SEWAGE WORKS JOURNAL

VOL. XXI NOVEMBER, 1949 No. 6

Special Features

Dual-Fuel Engines—Crooks

Food Waste Loadings—Owen

Copper Determination—Swope, et al.

Stream Standards—Agar

1949 Annual Index

OFFICIAL PUBLICATION OF THE

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

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Your prompt payment of 1950 dues will avoid interruption in receipt of SEWAGE WORKS JOURNAL as well as other Federation services. Undue delay may make it impossible for a complete volume of the JOURNAL to be furnished.

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325 Illinois Bldg. Champaign, Ill.

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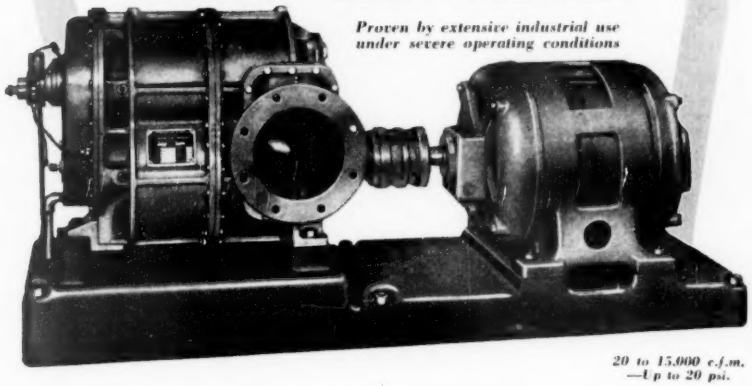
STANDARDAIRE BLOWER

EFFICIENT • QUIET • COMPACT

Proven by extensive industrial use under severe operating conditions



20 to 15,000 c.f.m. —Up to 20 psi.

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   Precision materials and select materials insure long life under continuous operation.

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STANDARDAIRE BLOWER
should be directed to The Chicago Pump Company, Exclusive Sales Representatives in the Sanitary Engineering Field.
Manufactured by
The Standard Stoker Company, Inc.

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A bimonthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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INDEX SERVICE

Sewage Works Journal is indexed regularly by *Industrial Arts Index* and *Engineering Index.*

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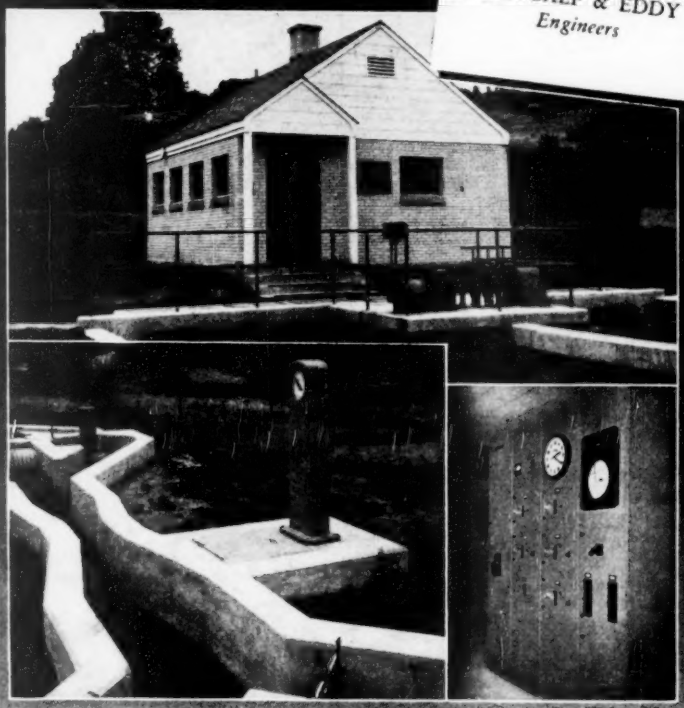
Sewage Treatment Plant

(Completed in 1946)

METCALF & EDDY
Engineers



To show that good things can come in small packages, here's a highly efficient sewage treatment plant in the less-than-1½ m.g.d. class. This well-designed installation, built by Munroe-Langstroth, Inc., Contractors, replaces a 50-year-old plant and handles the sewage treatment and disposal for a community of about 16,000 people. As in many sewage works, large and small, Builders Metering Equipment provides hour-by-hour flow data and permanent records essential to future planning. For Bulletins describing Builders Sewage Works Equipment, address Builders-Providence, Inc., (Division of Builders Iron Foundry), Providence 1, R. I.

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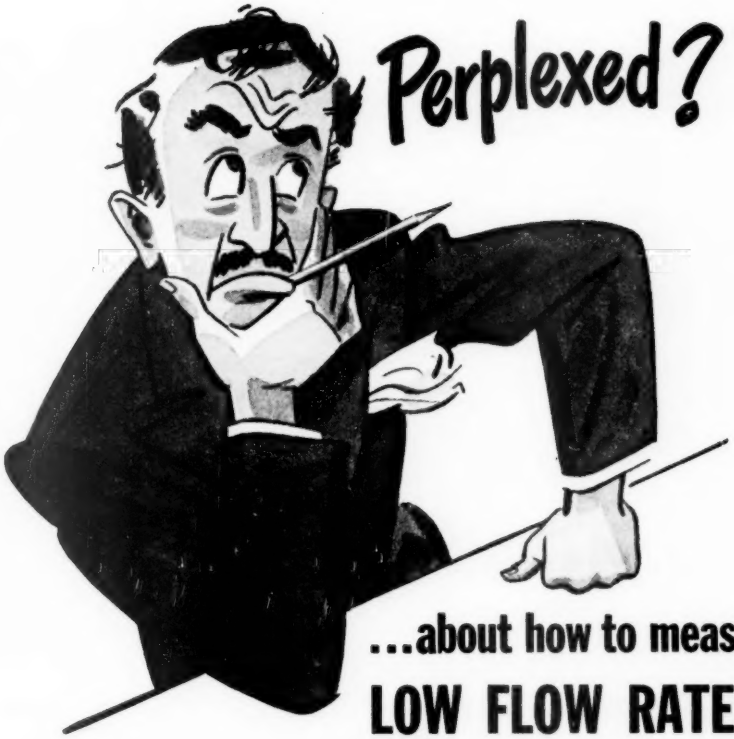
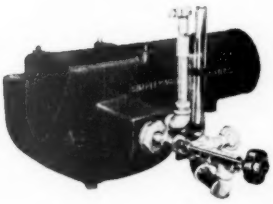


Perplexed?

...about how to measure

LOW FLOW RATES?



There's an easy way to solve your problems! Simplex Type S-Parabolic Flume Meters measure low flows with greatest accuracy! Compact in design, the cast iron measuring section is ready for immediate installation. Designed to provide self-scouring action, there are no pockets or grooves to catch sediment or solids. It operates under extreme low head and low flow conditions, and measures over a long flow range from maximum to 5% of maximum capacity.

This flume is available in sizes from 6" to 36" diameter inclusive and may be attached easily to larger pipe sizes by an eccentric reducer. Mechanical or electrical transmission and indoor or outdoor installation are optional. Send now for your free copy of bulletin 210—complete operation, installation, capacity data—to the Simplex Valve & Meter Company, 6719 Upland Street, Philadelphia 42, Pa.

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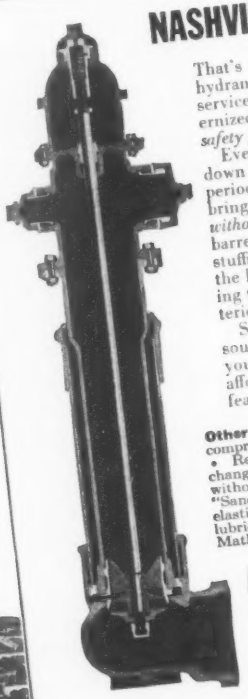
VALVE AND METER COMPANY

NASHVILLE, TENNESSEE



"One of America's Safest Cities"
The Mathews Firemen Say

That's the case when a city's fire hydrants are always ready and fit for service. Nashville uses Mathews Modernized Hydrants and they mean *safety plus.*

Even when a Mathews is knocked down by a truck, the unfit-for-service period lasts only so long as it takes to bring up a spare barrel and install it *without excavating.* The removable barrel contains all working parts. The stuffing box plate, cast integral with the head, prevents water from reaching the operating thread to cause deterioration from rust or sand.

Send for full description of this soundly designed hydrant and see for yourself why your community cannot afford to be without its *safety plus* features.

Other Mathews Features: Main valve true compression type • Head can be turned 360° • Replaceable head, nozzle outlets easily changed • Nozzle levels raised or lowered without excavating • Protection case of "Sand-Spun" cast iron for extra strength, elasticity • Operating thread only part to be lubricated • A modern barrel makes any Mathews good as new

MATHEWS HYDRANTS

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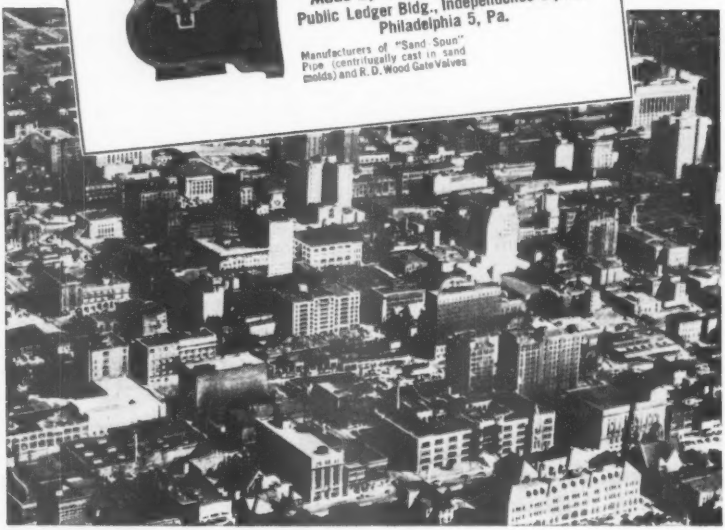
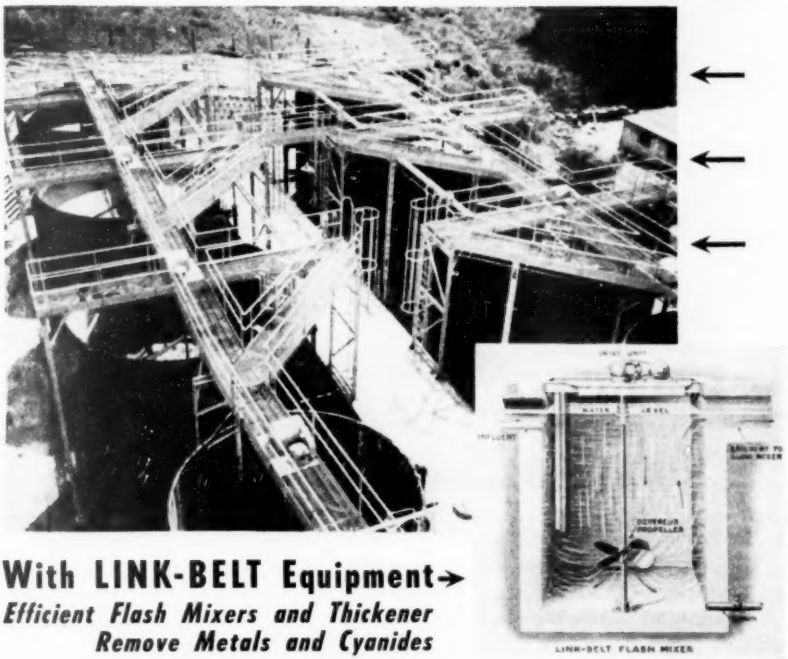
Manufacturers of "Sand Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves



Toxic Waste Water Made Harmless



With LINK-BELT Equipment →

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Elaborate metal working operations at the Meadville, Pa., plant of Talon, Inc., produce an average of 90,000 gallons of waste water daily, which must be treated to remove toxic elements, prior to discharge into nearby French Creek. Link-Belt equipment developed through broad experience in industrial and sewage treatment plants of every kind, provide thorough mixing of treatment chemicals, and removal of sludge, producing a crystal clear effluent.

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LINK-BELT FLASH MIXER

Link-Belt experience in the design of equipment for the treatment of water, sewage and industrial liquids is the broadest, and equipment developed by Link-Belt engineers comprises most every item required for complete results. Link-Belt engineers welcome your inquiries.

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Efficient power transmission machinery required to operate sewage and water treatment systems is included in the complete Link-Belt line.

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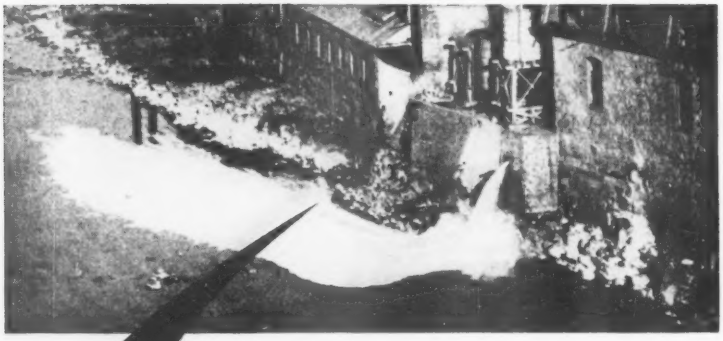
LINK-BELT COMPANY

Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Dallas 1, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8. Offices in Principal Cities.



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For Treatment of Industrial Wastes

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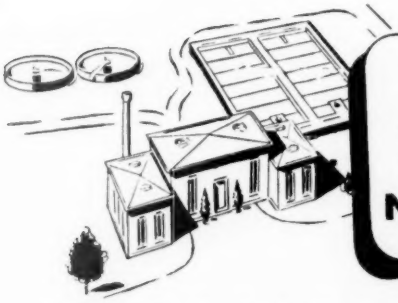

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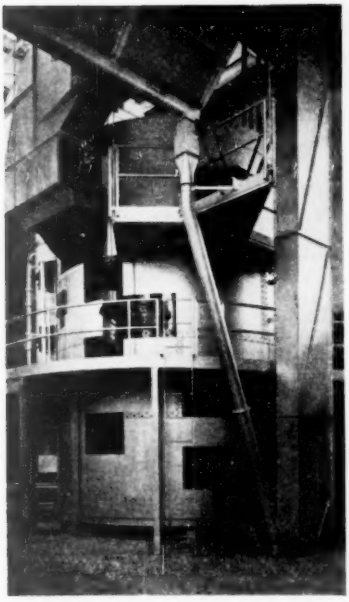
save on plant design—
plant operation—with
Nichols Incinerators



A Nichols Multiple Hearth sludge incinerator installation. Note the simplicity of design and compactness.

'Why is sludge incineration so important in modern sewage treatment plants?

BECAUSE . . .

★ Drying beds, digesters, unsightly, unsanitary sludge dumps are eliminated.

★ In many cases raw sludge is dewatered and incinerated without intermediate treatment.

★ Incineration provides a ready means for disposal of grit, screenings and scum.

★ Sludge produced by any basic method of sewage treatment is successfully incinerated, either digested or raw.

★ Experience shows incineration is normally cheaper than sludge hauling and dumping.

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Nichols Multiple Hearth Incinerators are serving cities with populations of up to two million.

Sludge drying and incineration in a fully automatic Nichols unit is the final step in modern sewage treatment. GET ALL THE FACTS. COMPARE COSTS AND OPERATION ADVANTAGES. Nichols engineers offer a competent source for consultation or direct planning. Use this knowledge to your profit.

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Koppers furnishes skilled workmen, competent supervision and special equipment to coat your pipe lines inside and out with Koppers Bitumastic* Enamel.

This *permanent* protective coating is processed from coal-tar pitch, a substance that has outstanding records in the battle against corrosion. Inside the pipe, the Bitumastic spun lining prevents rust and tuberculation and guards against the attack of sewage gases and acids. The Bitumastic exterior coating protects the pipe against moisture, corrosive soil and electrochemical reaction.

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Still Going Strong

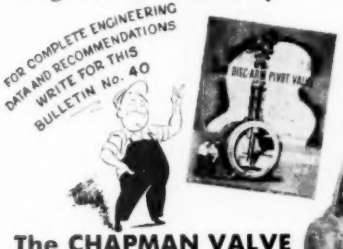
after more than 25 years are the first

CHAPMAN

DOW DISC-ARM PIVOT VALVES

More than a quarter of a century ago the first valves of this design were installed. And today these valves, and hundreds more, are giving excellent service . . . furnishing tangible evidence of unusual strength and reliability.

An improved type of butterfly valve, the Dow Disc-Arm Pivot Valve *applies the operating force to the proper point* . . . takes the deflection out of the lower half of the disc. Note below the advantages of this design . . . then write today.



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NO VIBRATION! Because of direct connection between disc and operating mechanism there is no vibration even at highest velocities.

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. . . NOW REDESIGNED FOR STILL HIGHER EFFICIENCY

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Built to keep pumping longer at lower cost these pumps are equipped with the highest duty bearings available, including double row, angular contact thrust bearing. Large size pumps also have a self-aligning, spherical roller radial bearing.

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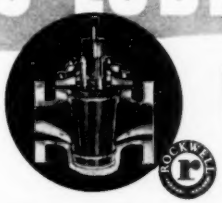

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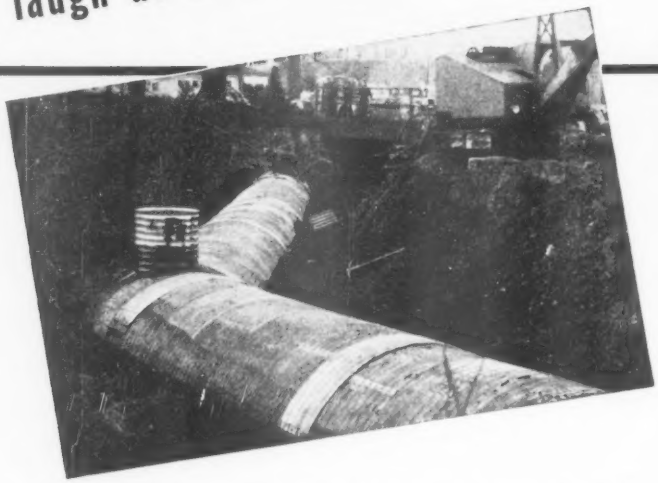

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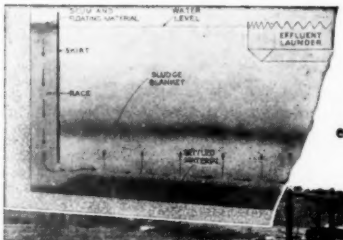

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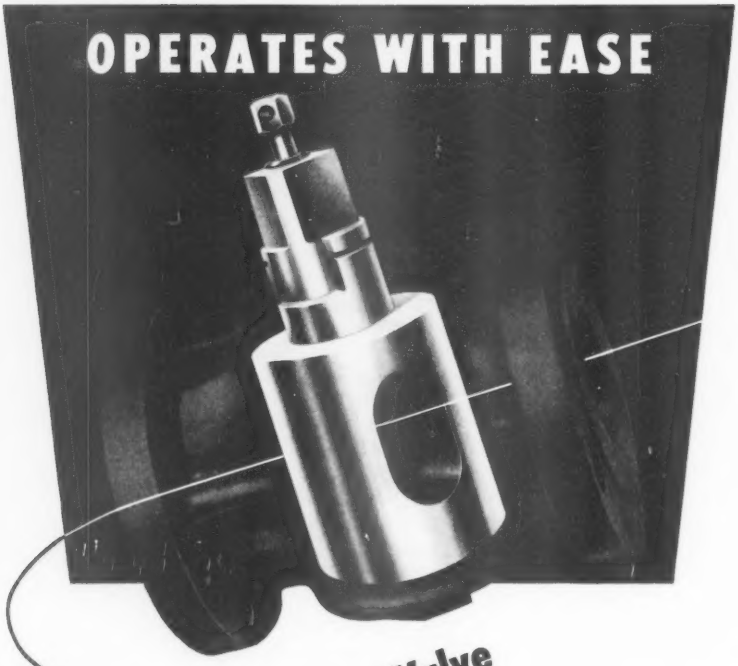

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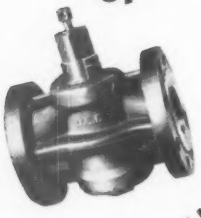

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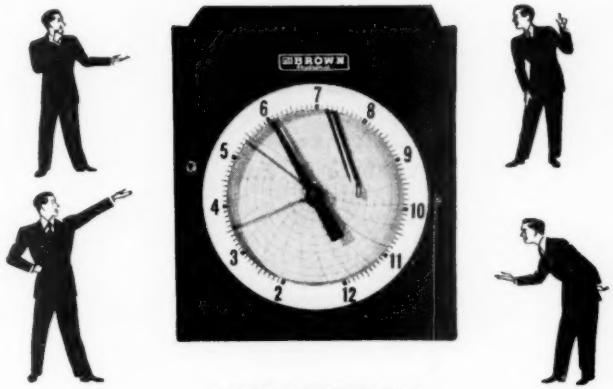

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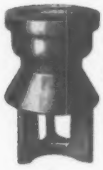

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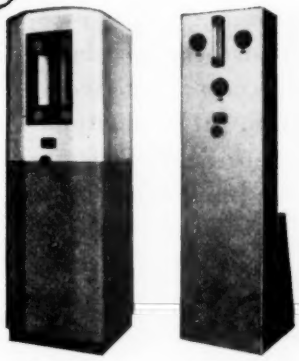

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SEWAGE WORKS JOURNAL

Official Bimonthly Publication — Federation of Sewage Works Associations

Volume XXI **NOVEMBER, 1949** **Number 6**

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois
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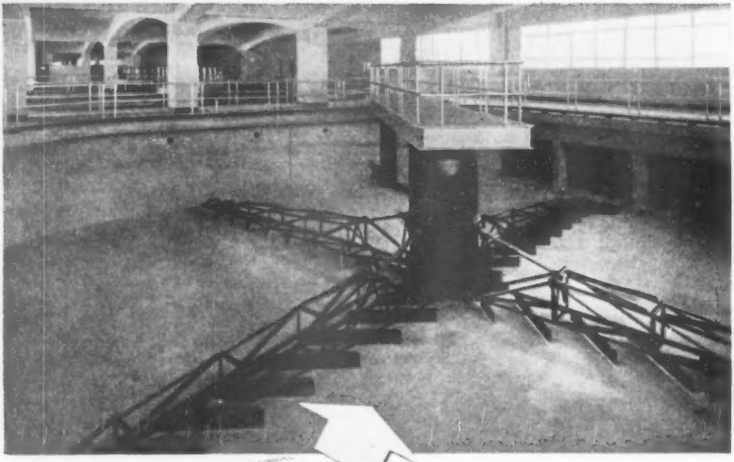

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RESEARCH — ENGINEERING — EQUIPMENT

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Sewage Works

THE DUAL-FUEL ENGINE AND ITS APPLICATION TO SEWAGE TREATMENT PLANTS *

By W. R. Crooks

Resident Engineer, The Cooper-Bessemer Corporation, Grove City, Pa.

The dual-fuel engine is an extremely valuable source of power for sewage treatment plants, not only because of its use of a by-product of plant operation, but also because of its versatility of application and economy of operation. Its obvious advantages are such that development has been extremely rapid—so rapid, in fact, that the commercial aspect often has been forgotten and the work pursued like a hobby.

Experimental work with the dual-fuel engine has lead to the most efficient engine known, with a thermal efficiency of 40 per cent at full load. It has lead, also, to an extremely economical source of power having an extremely low maintenance cost. One dual-fuel engine completed 26,400 hr. of operation in the spring of 1949. This engine was operated at overload for a considerable part of the time, so that the load factor for the elapsed time it was in operation is more than 100 per cent. During the first overhaul, a new set of piston rings was all that was necessary to start this engine on its second lap of producing power. It was not even necessary to grind the valves.

This paper describes briefly what the dual-fuel engine is, the need for this engine, its development and present status, and its advantages in a sewage treatment plant.

* Presented at the 23rd Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cleveland, Ohio; June 22–24, 1949.

Meaning of Dual-Fuel

The dual-fuel engine has been officially defined by the Diesel Engine Manufacturers Association as "One which uses all oil fuel on the diesel cycle, or predominantly gaseous fuel with oil fuel ignition, and is fully convertible from one fuel to the other." The term "gas-diesel" is officially defined as "A dual-fuel engine that is not instantly convertible." The only difference between the gas-diesel and the dual-fuel engines is that some parts of the fuel system may be altered to convert a gas-diesel to a dual-fuel engine. Cooper-Bessemer dual-fuel engines were brought out prior to the definition by D.E.M.A., so were called gas-diesel engines. However, they are dual-fuel engines, being instantly and, if desired, automatically convertible from fuel oil to 95 per cent gas and 5 per cent pilot oil for ignition purposes. The terms gas-diesel and dual-fuel are used synonomously in this paper.

Some preliminary work was done on the dual-fuel engine in 1928. The original design was rather expensive, and performance was not too satisfactory. The conclusion was reached at that time that the market for such an engine was quite limited and that there was little to be gained in developing it commercially. Many users of heavy-duty gas engines were then using waste gas from the oil industry or sewage treatment plants as their

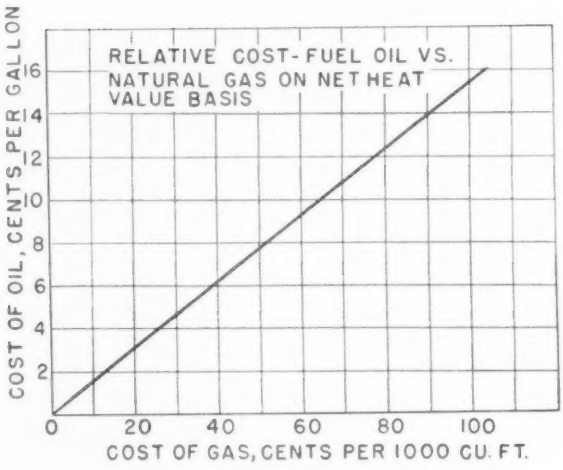

FIGURE 1.

source of fuel. Where low cost gas was not available, diesel engines were offered as a source of power.

Diesel fuel oil sold for approximately 4¢ per gal., which is comparable to gas costing 25¢ per 1,000 cu. ft. As the price of fuel oil increased and long-distance gas pipelines became more numerous, it became apparent that there was an economic need for the dual-fuel engine. Such an engine permits the use of gas when it is available, yet does not disturb engine operation when gas is not available due to extremely cold weather or failure of the gas supply. With fuel oil

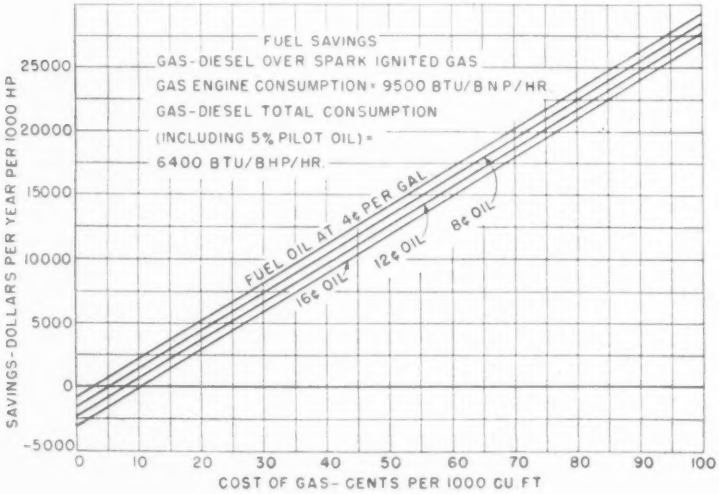

FIGURE 2.

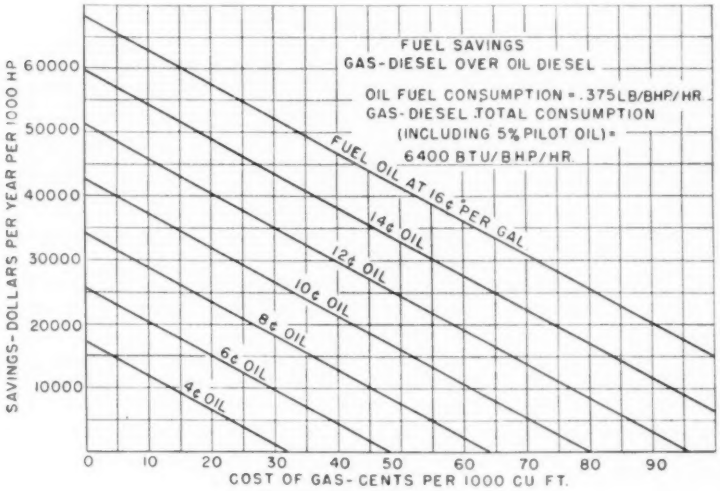

FIGURE 3.

selling for 10¢ to 15¢ per gal., the savings are obvious (see Figure 1). Figure 2 shows the yearly saving per 1,000 h.p. of a gas-diesel over a spark-ignited gas engine for various prices of oil and gas. The savings obtainable by using a gas-diesel over an oil diesel engine are shown in Figure 3.

Basic Principles

The basic principle of the dual-fuel engine is quite simple. Air and gas

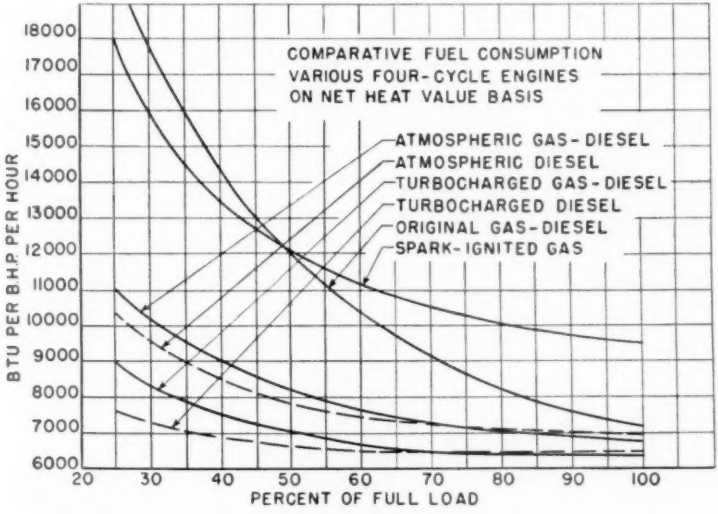

FIGURE 4.

for combustion are fed into the cylinder ahead of the compression stroke, just as in the conventional gas engine. At the end of the compression stroke the fuel is ignited by injecting a small amount of fuel oil into the cylinder.

Such a combustion cycle was considered impossible from the time of the perfection of the heavy-duty gas engine (about 1910) until the commercial development of the dual-fuel engine in 1945. Because the high compression in the diesel cylinder is hot enough to ignite even heavy fuel oil, it was assumed that a combustible mixture of gas and air would start burning before the completion of the compression stroke. It was logical to assume that pre-ignition would be so severe that such an engine could not be operated. Every manufacturer of gas engines had found that compression greater than 115 to 125 p.s.i. was very sensitive to pre-ignition and it was only possible to reach such compressions after carefully removing the "hot spots" from the cylinder and pistons. Engineers early learned that a mixture of approximately 1 volume of 1,000-B.t.u. gas and 10 volumes of air was a perfect air-gas ratio and gave the maximum power in a gas engine. All experimental work in attempting to increase the compression was done with this perfect mixture until the dual-fuel development. As soon as the mixture was changed to 1 part of gas to 15 to 30 parts of air by volume, it was found that the combustible mixture of air and gas could be compressed to at least 550 p.s.i. without a trace of pre-ignition or combustion knock. The basic principle of the dual-fuel engine is as simple as that. There were numerous details to be worked out, however, before the basic principle could be made commercially available. The old adage "Trifles make for perfection, but perfection is no trifle" applies here.

Figure 4 shows the comparative heat consumptions of various types of 4-cycle engines and indicates graphically the reduction in fuel consumption by the dual-fuel engine.

Many dual-fuel engines are operating in practically every type of stationary service in sizes ranging from

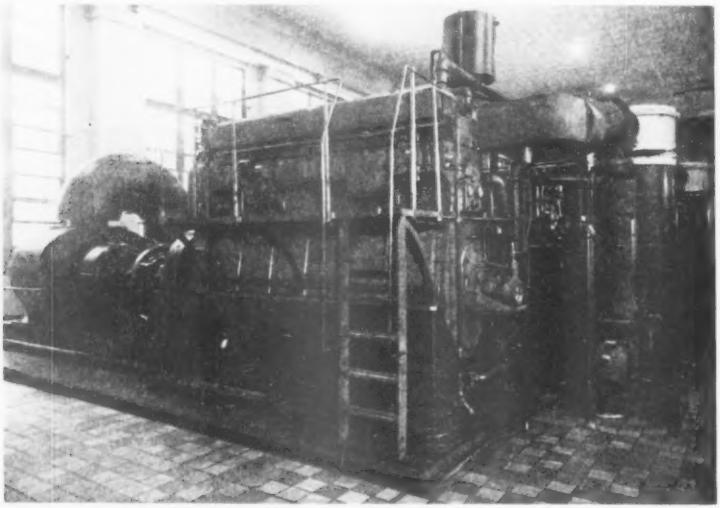

FIGURE 5.—Two dual-fuel engines in sewage treatment plant service.

125 h.p. to 3,400 h.p. Dual-fuel engines have been perfected to the point where, by comparison with the conventional high-grade spark engine, they require 30 per cent less fuel at full load and 50 per cent less fuel at quarter load to produce 1 h.p.-hr. By supercharging, the output of any given engine has been increased as much as 75 per cent. This increased power from a given foundation and engine size appreciably reduces the building and installation costs.

Cooper-Bessemer gas engines have been in successful operation in sewage treatment plants since 1933. They have made a good record, but from a knowledge of disposal plant operations it is believed that the dual-fuel engine is even better fitted for this service (Figure 5) because:

1. It provides a source of power as a diesel engine to put the sewage disposal plant into operation, thus freeing the plant from standby charges for electrical power.

2. It eliminates the need for separate heating equipment both for the building and for starting the digestion process, as the waste heat boiler and jacket water provide the necessary heat. This combination provides an over-all thermal efficiency of 65 per cent.

3. It is a source of a definite amount of dependable power at all times. If the sewage gas supply is not enough to meet the power demand, other gaseous fuel (such as natural gas) or fuel oil will automatically make up the additional fuel requirements.

4. It will give long life due to extremely thorough combustion and relatively low operative temperatures.

Recent developments, such as running the gas through purifiers, effective protection of the parts against the corrosive action of sewage gas, use of chrome plated top ring, and basic-type lubricating oils, promise to reduce cylinder and valve wear to that obtainable with the use of the highest grade of fuels.

With the higher cost of fuel and the greater amount of power obtainable from each cubic foot of sewage gas, it is definitely indicated that more and more dual-fuel engines will be used in sewage treatment plants.

ESTIMATING FOOD WASTE LOADINGS ON SEWAGE TREATMENT *

By Mark B. Owen

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In a recent paper (1) the author has discussed the probable future of household garbage disposers and, as a result of a survey in Indianapolis, Ind., has offered the prediction that by 1965 about 45 per cent of residences in the study area will be so equipped. Outlined herein is a method of forecasting necessary design data to care for the added loadings involved in handling food wastes in municipal sewage treatment plants.

General

No function of local government is older than that of garbage and rubbish disposal. Nevertheless, no service of community living has been so universally abused, neglected, and ignored as the disposal of organic wastes.

Anyone who is, or has been a municipal housekeeper will agree that "Out of sight, out of mind" describes the attitude of the average householder toward the disposal of sewage and garbage. That is certainly true of sewage, because all the householder has to do in a modern home is depress a neat little lever and the sewage problem is solved as far as he is concerned.

Household garbage disposal is not so simple. Now, however, a "neat little lever" is available to ease the householder's pain—the kitchen garbage disposer. At the same time it will provide growing relief from the headaches of the garbage collection department. Probably it will never, in our time, become a 100 per cent remedy.

During the past 15 years several articles have been written concerning the effect of garbage disposers on the sewage system. Some emphasize the probable cost effect on sewage treatment. However, sewage treatment takes only one part of the tax dollar. The problem should be examined on a broader base—that is, the over-all effect on the taxpayer. Although disposal of household food wastes to sewers eventually may have some appreciable effect on the cost of sewage treatment, it will at the same time have the effect of reducing the cost of garbage collection and disposal. Thus, it represents one budget item to the sewage plant operator, but two or more items to the municipal housekeeper.

The ensuing statements and discussion are more or less influenced by thinking in terms of the municipal housekeeper. More particularly are they based on the following:

1. No experimental, or pilot plant of appreciable size, known to the writer, has been operated using ground garbage from kitchen disposers.
2. The character of garbage from industrial grinders is not like that from kitchen grinders.
3. Never in this century will all of the dwellings of an average community be equipped with kitchen disposers.
4. Garbage entering the sewage treatment plant from household disposers will have an effect on the treatment process quite different from that where industrial grinders are used and the material discharged directly into digesters.

* Presented at 22nd Annual Convention, Central States Sewage Works Association; Chicago, Ill.; June 17–18, 1949.

What is Garbage?

Garbage means many things to many people. Most laymen think garbage comprises everything discarded from the home except ashes. Even in municipalities where garbage has been collected separately for years a fantastic assortment of things other than garbage is deposited in the garbage receptacles.

As used herein garbage is defined as the animal and vegetable waste resulting from the handling, preparation, cooking, and consumption of foods in kitchens, stores, markets, hotels, restaurants, and other places where food is stored, cooked, or consumed. It does not include bottle caps, razor blades, cutlery, paper, broken glass, and similar items frequently found in so-called clean garbage.

Quantity and Character of Garbage

During the normal course of living, people produce and discard waste materials, both liquid and solid. As our mode of eating and living changes, so changes the quantity and character of human wastes.

More and more food products are being put up in "throw-away" containers. Some are combustible containers and many are of metal and glass. This situation is increasing the quantity of rubbish discarded per person and may eventually decrease the per capita garbage rate.

The quantity of garbage produced in a community is influenced by the geographical location of the community, the seasons, and the habits and economic status of its inhabitants. For the purpose of estimating the quantity of garbage produced in communities of the East North Central States it is thought that 0.5 lb. per capita per day is conservative. It might be mentioned in passing that although the per capita garbage quantity has remained unchanged over the past 20 or 30 years, the rubbish quantity has increased substantially.

Climatic zones affect both the quantity of refuse produced and the character of garbage. In the South where the growing season is longer, more fruits and vegetables are consumed, thereby producing garbage of higher moisture content during more weeks per year, and thereby raising the average annual moisture content above that usually found in the North.

The moisture content of garbage will vary from about 70 per cent to 80 per cent by weight. Volatile, or combustible content will range from 15 per cent to 27 per cent; ash, or mineral matter is about 3.8 per cent.

Garbage Disposal Services

Garbage collection and disposal is one of the most expensive of municipal services. Moreover, it is the source of more complaints from residents than any other function of the municipal housekeeper.

Whether the disposal method be incineration, reduction, sanitary land fill, hog feeding, or just plain dumping, the collection cost may well be three times the disposal cost. Gross inefficiencies are inherent in the best of collection services, as seen in data from a recent time study of a garbage collection service.

The collection equipment used in the service studied consisted of truck-tractors and trailers. When the trailer was loaded it was unhooked from the truck and an empty trailer was attached. This transfer was made "on the spot," so a minimum of lost time and travel was experienced. In the area studied there were 7,371 dwellings containing 7,946 families. Two collection crews of three men each provided the service during a 10½-day period.

During this period the crews traveled a total of 362.7 miles, and worked 70 hr. and 16 min. Of the total travel, about one-third (120.6 miles) was on actual collection service. Of the total working time, 68 per cent was devoted

to actual collection work. The remaining 32 per cent of the time of three men was spent riding from the garage to the collection area, from the collection area with loaded truck and trailer to the disposal point, and from the disposal point back to the collection area or to the garage. Further, the vehicles traveled 139.1 miles while empty.

Although the type of equipment used is not considered sanitary and is now generally out-moded, it did keep the ton-mile cost of collection at a practical minimum. Garbage hauls of 5 miles are not unusual, and in metropolitan areas hauls of 12 to 15 miles are not uncommon.

In Muncie, Ind., a city of 60,000, where the average haul is about 6 miles, it was calculated that if 75 per cent of the garbage were eliminated from the collection and disposal service, the annual saving to this service would be about $24,000. As the Muncie budget item for refuse service is about $90,000 per year, the potential saving is of considerable importance. Therefore, any appraisal of the kitchen garbage disposer should be on the broader basis—as viewed by the municipal housekeeper, and not confined to its probable effect on sewage treatment facilities alone.

Sewage Characteristics

Later in this paper the potential effects of kitchen garbage disposers on sewage treatment facilities are discussed, as applied to Muncie, Ind., a community that has been aptly called "Main Street, U. S. A."

A recent sanitary survey of that city provides the following data on the sewage:

Present population	60,000
Sewage flow (g.c.d.)	200
Suspended solids (p.p.m.)	200
Susp. vol. solids (p.p.m.)	140
5-day B. O. D. (p.p.m.)	130
Total solids (p.p.m.)	1,050
Total vol. solids (p.p.m.)	437

For the undigested sewage sludge the ultimate analysis is as follows:

Component	Dry Solids (%)	Combustible Solids (%)
Carbon	45.1	56.5
Hydrogen	6.1	7.6
Oxygen	24.4	30.6
Nitrogen	3.3	4.2
Sulfur	1.0	1.1
Ash	20.1	—
Total	100.0	100.0

Effect of Disposers on Sewage Treatment Facilities

In the past some very definite conclusions and statements have been published regarding the effect of garbage from kitchen disposers on sewage treatment facilities. Apparently the experience at plants where garbage from industrial grinders is discharged directly to digesters has had a major part in the thinking behind such conclusions. Disposer garbage going through the treatment plant with sewage most certainly will not have the same final effect as industrial grinder garbage going to the digesters direct.

No plant has ever received disposer garbage in any but relatively minute quantities. Only at Indianapolis, Ind., has a sewage plant ever received and taken through the treatment process industrial grinder garbage for any length of time or in any appreciable quantity. There, from June through December, 1935, over 15,000 tons of garbage were disposed of through the sewage treatment works. The late Cecil K. Calvert was plant superintendent during that operation and in his report of the experience said, "Sludge production was a little higher, perhaps, than usual, but was almost normal."

His report shows that the increase in raw sewage solids due to garbage was 5 per cent total solids and 13 per cent suspended solids. The garbage was from an industrial grinder equipped to produce solids of ¼-in. size and under.

Mr. Calvert also said, "It appears on first thought that garbage should add a very heavy load to that which the sewage plant must treat, but every sewage plant always receives a considerable amount of waste from the domestic preparation of food. Besides juices, any solids fine enough to pass the sink strainer are flushed into the sewer. In any case, the additional load (from household grinders) need cause the sewage plant operator no alarm. . . . After seven months operation, the conclusion reached is that ground garbage offers no serious problem in sewage treatment and such disposition appears to be more economical than methods now in use."

Any calculations of solids loadings —either garbage, or sewage, or both— should be made on a comparable basis of either total solids or suspended solids. Nevertheless, in many discussions of the effect of ground garbage on sewage treatment facilities the total solids of garbage are used whereas only the suspended solids of sewage are considered. At the same time, in calculating sewage sludge quantities, total solids are used. On the basis of past thinking and methods of calculating the net effects, how can anyone arrive at sound conclusions, much less make positive statements as to plant requirements or added treatment costs?

There can be no objection to computations designed to depict only the worst possible condition that could arise due to ground garbage being admitted to sewage plants. However, it is confusing, to say the least, and technically unsound to overlook or ignore the practical aspects of the problem.

Computations made in the past assume that all of the garbage solids will settle out and add that much more to the present plant load. That assumption is definitely erroneous.

It has been established that the household disposer uses from 1 to 2 gal. of water per person per day, equivalent to 2 to 4 gal. of water per pound of wet garbage. In the laboratories of the writer's firm are three types of disposers. Tests were run using three gallons of water per pound of garbage.

Assuming a sewage flow of 100 g.c.d., it was found that the garbage solids would be as follows:

Series	Total Solids (p.p.m.)	Suspended Solids (p.p.m.)	Per Cent Suspended
A	132	54	41
B	127	51	40
C	125	37	30

Garbage in Series A and B was collected from various fire stations and ground with distilled water. Series C garbage was from a private residence and ground with tap water. Incidentally, raw and filtered samples of Series C were diluted 20 to 1 and incubated for 18 days to determine the oxygen demand. The results were as follows:

	B. O. D. (p.p.m.)		
	5 days	9 days	18 days
Raw	340	360	540
Filtered	130	180	220

It is believed these data are indicative of what may actually take place in a large scale operation.

In view of the above, is it accurate or practical to use total garbage solids in measuring the theoretical effect on sewage treatment in trickling filter and activated sludge plants? Will not a substantial quantity of dissolved garbage organics become mineralized the same as sewage solids, and leave the plant in the effluent?

The similarity between the ultimate analyses of raw garbage and raw sludge, based on the dry solids of each, is shown in the following:

Component	Sludge	Garbage
Carbon (%)	45.2	45.1
Hydrogen (%)	5.6	6.1
Oxygen (%)	31.6	24.4
Nitrogen (%)	2.1	3.3
Sulfur (%)	0.3	1.0
Ash (%)	15.2	20.1
Total (%)	100.0	100.0

If garbage alone having such an analysis entered an activated sludge or trickling filter plant via the influent sewer, would the effluent or final sludge be expected to be materially different than that from the sewage alone?

Ordinarily about $^2/_3$ of the total solids of sewage are in solution and the final sludge about equals the quantity of suspended solids. Now it appears that about $^2/_3$ of the total solids of garbage from kitchen disposers may arrive at the sewage plant in solution. Certainly not much more than $^1/_3$ of the garbage solids will become sludge.

If the average production of garbage is 0.52 lb. per capita per day, equal to 0.13 lb. of dry solids, it does not seem unreasonable to say that the added sludge load due to garbage will be between 0.13 lb. and 0.13/3 lb. (or 0.044 lb.) per person per day. It does seem unreasonable to use the 0.13 lb., as the actual quantity lies somewhere between the two figures.

Sample Calculation

Using factual data obtained in the Muncie survey and information and data discussed above, calculations portraying the possible minimum and maximum sewage plant loadings can be made. It should be noted that only 50 per cent of the dwellings are assumed to have disposers, in accordance with the saturation of sales expected by 1970. Furthermore, the calculations in Table I assume that 95 per cent of the suspended solids of sewage go to digestion, and that, in one case, 100 per cent of the total solids of garbage go to digestion.

Table I is intended to depict the maximum and reasonable minimum loadings. Using average garbage quantities—that is, the average of the total and suspended quantities—gives 13,910 lb. per day of digested sludge, or an increase of 12.6 per cent in dry digested sludge due to garbage.

TABLE I.—Basic Data of Sewage Plant Loading Due to Ground Garbage in City of 60,000

A.	Population		60,000
B.	Suspended sewage solids (lb. dry per day)		19,000
C.	Total garbage solids (lb. dry per day)		3,900
D.	Suspended garbage solids (1/3 of total) (lb. dry per day)		1,300
E.	Total dry solids, B+C (lb. per day)		22,900
F.	Total dry solids, B+D (lb. per day)		20,300
G.	Dry garbage solids, C as % of E		17.0
H.	Dry suspended garbage solids, D as % of F		6.5
I.	Increase in dry solids due to garbage, basis C (%)		20.5
J.	Increase in dry solids due to garbage, basis D (%)		6.9
K.	Volatile solids (lb. per day):		
		Basis E	Basis F
	Sewage sludge	13,300	13,300
	Garbage	3,120	1,040
	Total	16,420	14,340
L.	Digested sludge (50% volatile reduction) (lb. per day):		
	Basis E		14,690
	Basis F		13,130
M.	Digested sludge, sewage only (lb. per day)		12,350
N.	Increase in dry digested sludge due to garbage (%):		
	Basis E		18.9
	Basis F		6.3

Based on the calculations it is the writer's opinion that the sludge facilities of no sewage treatment plant will have to be enlarged more than one-eighth in the next 20 years due to kitchen garbage disposers.

It will be noted that the foregoing calculations are not truly representative of the conditions. If one approaches the problem from the standpoint of solids entering the sewage plant it will be found that the load is as follows:

Suspended solids only (lb.)	
In sewage	20,000
In garbage (40% susp. sol.)	1,560
Total	21,560
Increase due to garbage (%)	7.8

In this case it has been assumed that 40 per cent of the garbage solids are suspended. If the plant removes 95 per cent of the suspended solids and this goes to digesters, the increase in the digested sludge due to garbage is 7.2 per cent.

Although it does not appear accurate to use the suspended solids of sewage and the total solids of garbage for measuring the total load, it would probably be inaccurate to use total sewage solids and total garbage solids. For instance, the total solids of the above sewage was 1,040 p.p.m. If 400 p.p.m. were contributed by the city water, the sewage would contain 640 p.p.m., or 64,000 lb. per day as compared with 20,000 lb. used in the earlier calculations. In this case, the total garbage solids would be 5¾ per cent of the total load.

Conclusions

In appraising the economics of the kitchen garbage disposer one should not limit the considerations to the probable effects on sewage treatment, but should broaden the scope to include the interests of the municipal housekeeper as well as the householder.

When the householder deposits garbage in the kitchen disposer you may be sure it will be nearly pure garbage substance. Only by accident will it contain other materials and they will be beyond recognition when received at the sewage plant.

Water transportation is famous for its relative cheapness. What could be less expensive than water carriage of ground garbage by gravity, particularly when it has no appreciable effect on the hydraulics of the carrying system. Why not utilize the sewer system to transport the garbage of a community?

If the use of garbage disposers follows the sales pattern of most other household appliances, it will be more than 20 years before half the dwellings in the average community will be so equipped. When and if half the dwellings of a community are equipped with disposers, the sludge load at the sewage plant will not be increased by as much as 20 per cent. It will more likely be in the neighborhood of 10 per cent.

Reference

1. Owen, Mark B., "The Future of Home Garbage Grinders." *Water and Sewage Works*, **96**, 5, 187 (May, 1949).

SLUDGE HEATING METHODS *

By R. A. Greene

Superintendent, Sewage Treatment, Jackson, Mich.

Almost continuous research has been going on in an effort to provide more adequate heating systems for separate sludge digesters since the first of these units was put in operation some 25 or 30 years ago. The tempo of this work has increased with the passing years because of the greater importance placed on this part of the treatment plant. Due to the increased utilization of the gas produced from the digestion process and the importance of temperature as one of the main factors affecting digestion, a method of heating has been sought that not only is adequate, but also provides maximum flexibility of operation.

The heat requirements which must be met by any type of heating system are composed of two main parts. First, and in practically all cases the largest, is the heat required to raise the incoming raw sludge from its natural temperature to the temperature desired in the digester. Second, is the heat lost through the external surfaces of the digestion tank. There are other factors which might affect the heat requirements to a minor degree, but it is believed that they would constitute a small fraction of the total.

The heat required to raise the temperature of the raw sludge to the temperature of the digestion tank is a straightforward calculation. The specific heat of the sludge is generally taken to be the same as for water. The heat required, in B.t.u., is equal to the product of the pounds of raw sludge and the temperature difference between the raw sludge and the digester temperature. The heat lost through the surface area of the digester is more difficult to state when attempting to apply a general formula applicable in all cases. It is a composite of several factors, and can be determined by the conductivity of sludge films inside the digesters, the conductivity of the material of which the tank is constructed, and the conductivity of the air or earth in contact with the outer surface of the digester. It appears, in general, that to raise the temperature of the raw sludge to the temperature of the digester would require 70 to 80 per cent of the total heat requirements, and that 20 to 30 per cent would be required to compensate for heat losses through the surface of the digestion tank where earth was banked around the outer walls of the tank.

Several methods of heating have been used in an attempt to meet the above-mentioned heat requirements. The heating systems devised for this purpose have been tried not only as to their ability to meet the requirements demanded by the digestion process, but also as to the efficiency of the particular heating devices themselves. The sewage plant operator is interested, in most cases, in meeting the heat requirements of the digestion process with the lowest total amount of B.t.u. contained in the fuel being used. The operator is always interested in the flexibility of the heating system, as it is not regular routine operation which causes alarm, but those circumstances which are somewhat out of the ordinary. Another test which any heating system must pass is that of maintenance cost. Operators may still be inclined to look on the digester as an unwanted appurtenance, but they do realize the importance of the smooth functioning of

* Presented at 24th Annual Conference, Michigan Sewage Works Association; Traverse City, Mich.; May 23–25, 1949.

a heating system, without undue maintenance cost, as a real help in the overall treatment process.

Heating Systems

Some of the heating systems which have been used are as follows:

(1) The passing of steam, generated in a boiler, directly into the digester in most cases requires softening of the boiler water supply. It also requires considerable attention, and for these and other reasons this method has never gained wide acceptance, although it is a very direct method of heating. If thermophilic digestion were the principal consideration, this method of heating would come in for greater consideration. In the experimental work on thermophilic digestion carried on at the Jackson, Mich., sewage treatment plant, ejection of steam directly into the digester was the most satisfactory method tried. About 75 per cent of the B.t.u. content of the gas burned in the boiler was transferred to the digester as heat.

(2) The ejector type heater hardly has been used enough to be considered, although it also was used at Jackson in connection with the thermophilic digestion experiments. This equipment consisted of an ejector through which sludge from the digester or raw sludge was circulated. The heating chamber was connected to the ejector and the heat from the burned gas, along with the hot gas fumes, were to be drawn into the digester by the velocity of the sludge passing through the ejector. The heating device proved to be very inefficient; the velocity of the sludge did not appear to be great enough to draw the heat generated by the burning gas into the digester.

(3) The method of preheating the raw sludge in a tank in which steam coils are inserted has been used to some extent. Sludge from the digester was also brought back into the preheating tank if necessary to keep the digester temperature at the desired level. This method never gained wide acceptance because: (a) some difficulty was encountered in pumping the hot raw sludge; (b) odors were caused by heating the raw sludge in an open tank; (c) sludge caked on the steam coils; and (d) excessive time and labor were consumed in heating the sludge due to the intermittent manner in which it was necessary in most plants to operate this type of heating system.

(4) The passing of raw or digesting sludge through steam has been used only slightly. It was found that the sludge would cake on the inside of the coils to such an extent that in a short time little heat would be transferred from the steam bath to the sludge.

(5) Heating coils mounted on the interior walls of the digester and through which hot water from a boiler is circulated have been more widely used than any other type of heating system. In most cases this has proved to be a good method of heating digesters. Nevertheless, the system does have a sufficient number of drawbacks to cause strenuous efforts to be made by sewage plant operators, and especially by equipment manufacturers, to devise a better method. In recent years, the wide acceptance of this heating method has been effectively challenged.

(6) The external type heating system, in which the sludge from the digester or the raw sludge is circulated, is challenging the heating coil method. The external type heater may be of the combined heater and heat exchanger type, or it may be a heat exchanger with a separate gas heater or boiler furnishing hot water. The last two methods are the most widely used, and for that reason more consideration is given herein to the advantages and disadvantages of both.

Coils vs. External Exchangers

Soon after separate sludge digestion was accepted as general practice, heating coils became widely accepted as the

standard type heating system. This was apparently not because of the universal acclaim by sanitary engineers that it was good in all its aspects, although in the light of past experience it does appear correct to state that in the majority of heating coil installations the performance of these units has been satisfactory. Heating coil systems designed with a hot water boiler having proper controls and sufficient heating coil surface area inside the digester have given excellent service for many years with little maintenance. It should be pointed out, however, that lacking in this respect, experience has proved troubles to be in prospect when sufficient heating coil surface area is lacking. The same amount of heating coil surface area is not required for a digester containing 3 per cent sludge as for one containing a heavier sludge; that is, the more concentrated the contents of the digestion tank the less transfer of heat takes place per square foot of heating coil surface area when all other factors remain the same. Many digester heating systems were designed to heat the digester contents when the digesters were operated as single stage units. Preference of the plant operator for stage digestion left the primary digester carrying about 75 to 80 per cent of the heating load with insufficient heating coils. In those installations where such conditions exist, the temperature of the hot water from the boiler had been raised in an effort to meet the heat requirements. This has often resulted in progressive caking of sludge on the heating coils.

Caking on heating coils is one of the chief faults of this type heating system and places definite limitations on the flexibility of systems where it occurs. It has become almost axiomatic that the hot water entering heating coils should be kept below 140° F. to avoid forming this insulation on the coils. This, however, has not always been true. The hot water entering the coils at the Jackson sewage treatment plant during a considerable part of each of the past eight or ten years has been above 140° F. No appreciable caking on the coils has been experienced during this time. The heating coils in the plant have become embedded in sand, which settled to such depths in the digestion tank as to form very good insulation around the coils. These same coils were used to aid in the heating of the primary digester during the experimental work on thermophilic digestion. Over this period, approximately three years, the hot water entering the coils was just below boiling. When inspected after completion of the experiments, very little scale or caking was present, although the coils were embedded in sand, the gradual decrease in the effectiveness of the coils showing that the deposition had occurred over a considerable period of time.

Although instances such as the one cited speak well for coils, it is known that sludge caking on heating coils has been and still is a nuisance. It is also known that heating coils do spring leaks for one reason or another. When trouble is encountered with coils, their location makes repairs on them a major task, not only because of the immediate damage, but also, in many instances, because of the effect on the entire operation of the treatment works. The digester must be emptied to make the repairs, leaving one-digester plants with no place to pump the raw sludge and cutting the digester capacity of the larger plants while the repairs are being made. The seriousness of the breakdown of coil heating systems in plants where they have occurred, and the fear of such breakdowns in other plants, has caused plant operators and designing engineers to look in the direction of the external heater as an answer to these problems. There are on the market today external heaters designed to meet the heat requirements of any size

of digestion system. All operating parts are located outside the digester, where the necessary cleaning and repairs may be made. The external combined heater and heat exchanger is equipped with a circulating sludge pump, which circulates the digester contents through a water bath at controlled temperatures at the rate necessary to meet the heat requirements of the digester. This type heating system may be equipped to maintain the desired temperature in the digester by automatic operation. The external heat exchanger is also equipped with a circulating sludge pump that circulates the digester contents through the heat exchanger, where the sludge piping is surrounded by circulating hot water furnished by an outside source. This type may also be equipped with automatic operation controls. Either of the two methods of external heating may operate continuously or intermittently. Where the flow of hot water circulated and the flow of circulating sludge are both controlled there appears to be a greater transfer of heat per square foot of heating surface area than can be obtained from the combined heater and heat exchanger. The combined type is a more compact unit, and on single-digester installations would in most instances be less costly to install.

The heat transfer coefficient, which is the number of B.t.u. per sq. ft. per hr. per degree difference between the sludge and hot water, decreases rapidly as the concentration of the sludge increases. This applies to both the heating coil system and the external heating system. With coils, the heat transfer coefficient has ranged from 39 (digester contents approximating the concentration of supernatant liquor) to less than 10 (digester contents made up of thick sludge). The heat transfer coefficient is much higher for the external heater, a value of 240 having been attained by circulating clean water instead of sludge through the exchanger. This value is reduced rapidly as the per cent solids in the circulating sludge increases, but does not approach the low figure that results from the use of coils under the same conditions. The film of sludge, whether on the inside or outside of the heating surface, reduces the heat transferred.

There are some points in common between the external type heating system and the internal type represented by heating coils inside the digester. Both can be readily adapted to use jacket water from a gas engine as the source of hot water. Both, when equipped with the proper controls, can furnish heat desired in other parts of the plant. The inaccessibility of heating coils for maintenance purposes and the ready accessibility of all parts of the external heater appears to be the main point around which the preferences hinge. A comparison of the two types on some specific points is as follows:

(1) It is often stated that when the external type heating system is used, the cold sludge is raised to the desired temperature before introduction to the digester. These heaters are designed so that raw sludge may be passed through the heater before it reaches the digester. The raw sludge may also be mixed in any desired proportion with the seeded sludge in the digester. The mixing with seeded sludge may have definite advantages as an aid to more rapid digestion, but it seems unlikely that the temperature of the cold sludge would be raised appreciably. In the average plant, the time consumed in pumping raw sludge constitutes a small fraction of the entire day. However, heating of the raw sludge to the desired digester temperature constitutes approximately 75 per cent of the digester heat requirements. Nevertheless, external heaters are designed to operate continuously, or nearly so. This means that either the cold sludge would be pumped through the ex-

changer at such a rate that the temperature rise would be negligible, or the time consumed in pumping the cold raw sludge would be very great.

(2) Effective control of the digester temperature is sought by all plant operators, especially when full use of the existing digester capacity is needed. The external heater seems to have definite advantage at this point in that changes, which must be made on occasions, are more positive with the external heater because of the accessibility of all heating parts and controls.

(3) Recirculation of the digester contents speeds up digestion. This may be done by means of a circulating pump when using the internal heating coil system, but it is not likely that it will be done regularly. With the external type heater this recirculation is, of course, necessary. It does appear that if it is necessary to operate the external type heater continuously to maintain the desired temperature in a digester from which supernatant is to be drawn, it would have a harmful effect on the quality of the supernatant. The points of discharge of the circulated sludge can, however, be located to lessen this disturbance. One point of discharge is generally located in the scum layer usually present in all digesters. This should be especially advantageous in keeping the area warm and moist, and thereby digesting more of the solids in the scum layer than would otherwise be accomplished.

(4) Cost of operation is important. From the standpoint of power consumed in pumping, it appears that the advantage would be in favor of the heating coil system. Comparison of this method with the combined external heater and heat exchanger is basically one between the cost of pumping water and the cost of pumping sludge. The external heat exchanger system involves the cost of circulating both hot water and sludge. There is a very distinct possibility, however, that more effective use of the heating fuel may be attained with the external heater. Maintenance on a sludge pump runs higher than on a water pump. It also appears that there would be more time spent, on a daily basis, making adjustment on the external type heating system than on the internal heating coil system. However, this extra time is no doubt nullified by the greater effectiveness of the external units to do the job intended. When coils spring leaks or when they become caked or clogged, remedial measures are both costly and inconvenient.

At Dayton, Ohio, where an external heater of the combined heater and heat exchanger type has been in operation for approximately two years, Lloyd C. Huffman, plant superintendent, states that maintenance costs have been low. After one year in service, the fouling on the interior of the sludge pipes in the heater could be compensated for by raising the temperature of the water bath 10°F. A complete cleaning of the unit after the one year in service consumed 8 man-hours. This appears to be a very good record and speaks well for the effectiveness of the units.

(5) The rate which heat can be applied to the digester is of great importance on days when large amounts of cold raw sludge must enter the digester. The external type heater appears to be more flexible, in that heat may be more rapidly transferred to the digester without having any lasting effect on the effectiveness of the unit.

(6) It is no doubt more economical to install a heating coil system than the external type heating system in almost any size installation. This again comes back to the point of the accessibility of all parts of the external heater. If proper maintenance and control can more easily be made on the external type heating system, and more trouble-free results obtained, this original cost could soon be offset.

It has been demonstrated in many installations that heating with coils is practicable and effective. It has also

been demonstrated that coils are subject to caking with resultant loss of heat transfer. In recent years the combined external heater and heat exchangers, as well as boiler-fed external heat exchangers, have also demonstrated that this type of heating system is practicable and effective. It seems to be the answer to the weaknesses inherent in the heating coil system.

Acknowledgment

Grateful acknowledgment is made to Harry E. Schlenz, Pacific Flush Tank Company; J. Donald Walker, Walker Process Equipment, Inc.; and A. J. Fischer, The Dorr Company, for their contributions regarding the external heaters and heat exchangers produced by their respective companies.

"FORMERLY SEWAGE WORKS JOURNAL"

This is the last issue of SEWAGE WORKS JOURNAL to appear under that name. When monthly publication begins (with the January, 1950, issue), it will be under the new name

SEWAGE AND INDUSTRIAL WASTES

the JOURNAL of the Federation of Sewage Works Associations

The change in name results from action by the Federation's Board of Control at its meeting October 20, 1949, and is intended to express the increased concern of the Federation and its constituent state and regional associations with industrial waste disposal problems. It is intended, also, to state more clearly in its title the JOURNAL's enlarged editorial policy, already in effect over the past several years, of providing a clearing house and publication medium for technical information of value to both municipal and industrial waste treatment personnel.

IMPROVED METHOD OF VOLATILE ACID RECOVERY FROM SEWAGE SLUDGES *

By H. Heukelekian and A. Joel Kaplovsky

The existing method for determining volatile acids in sewage sludge (1) is wholly empirical. It consists of the straight distillation of 50 ml. or more of acidified sample diluted to 200 ml., and the titration of 150 ml. of the distillate. The method, though simple, is subject to a number of criticisms.

The concentration of solids, volatile acids, and mineral acid continuously changes during such a distillation process. These changes may increase the yield of volatile acids by virtue of the hydrolysis of complex materials by increased concentration of the added mineral acid. The presence of the sludge itself during the distillation is objectionable because of the possibility of hydrolysis. Thus, steam distillation is preferable to straight distillation because it eliminates some of the errors by keeping the volume of the distillation mixture constant. Steam distillation of the sludge-free liquor should prove to be an added improvement. It is also necessary to know the volume of the distillate which gives a more or less complete recovery. For these reasons, a new method was developed to eliminate the errors from the above sources, based on the distillation of a sample from which sludge was separated by ferric chloride treatment, vacuum filtration with filter aids, concentration of the filtrate, and steam distillation of the concentrated liquor after saturation with $MgSO_4$. The exact procedure of the proposed method is outlined in the addendum. It is the purpose of this paper to present the validity of this method in comparison with the older method, and to discuss the important factors that influence the recovery of volatile acids from sewage sludge. The importance of the following factors was studied: (a) type of distillation, (b) volume of sample taken, (c) volume of distillate, (d) separation of solids, and (e) addition of $MgSO_4$ to hasten the rate of volatile acid recovery. These are interrelated factors, but the importance of each is compared with the new method.

Experimental Results

Results presented in this paper in all cases are averages of accumulated data having only small mean deviations. It has been found, after numerous quantitative analyses for the individual volatile acids present in decomposing sewage solids, that the usual method of expressing total volatile acids as acetic acid gives low results. The acids found in the quantitative analyses were acetic, propionic, and butyric acids. Acetic and butyric acids predominated, and varied in concentration depending on the period of digestion. Propionic acid was often present in the mixtures, but in much lower concentration than either acetic or butyric acid. When the acid mixtures were expressed as total volatile acids it was always found that the average molecular weight of the acids was approximately 74 (propionic acid). Consequently, all results of total volatile acids are expressed on the more accurate basis as p.p.m. of propionic acid.

A sample of fresh solids was divided into various portions and treated according to the procedures outlined in Table I. The purpose of this experiment was to determine the effect of

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various methods of treatment and distillation of a given sample on the total recovery of the acids.

The results show that all the variables indicated have an influence on the quantity of volatile acids obtained. In the straight distillation when 50 ml. of sludge was employed, 16.5 per cent more volatile acids were recovered with equal volumes of distillate than with 200 ml. of sludge. As the values are higher with the smaller volumes of sludge employed, it appears that the recovery is dependent on the sludge volume and is not complete with 200 ml. of sludge distilled to 150 ml. The results also are affected by hydrolysis, by the presence of the sludge, and by increased concentration of acid in the distilling mixture during the progress of distillation. The error caused by these factors is indeterminate until these variables are eliminated.

Steam distillation of the sludge mixture in the absence of $MgSO_4$ shows that the value obtained with 150-ml. distillates is lower than with 600-ml. distillates. The volume of sample taken affects the values obtained, although not to the same extent as in straight distillation. The 50-ml. sample gave 11.4 per cent higher results than the 200-ml. samples. The difference between the 50-ml. and 200-ml. samples was only 1.5 per cent with the 600-ml. distillates. The addition of $MgSO_4$ to the distilling sludge mixture increased the rate of distillation, as indicated by the recovery of 76 per cent of the volatile acids in the first 150 ml. of distillate based on the total in the 600-ml. distillate with the 200-ml. sludge sample. The corresponding recovery for the 50-ml. sample is 70 per cent in the first 150-ml. portion of the distillate. The 50-ml. sample gave only 2.5 per cent higher values than the 200-ml. sample with the 150-ml. fraction of the distillate, and 6.3 per cent higher values with 600 ml. of distillate. Thus, with the addition of $MgSO_4$ to the distilling mixture, the differences due to the volume of sample and volume of distillate are lower than without the $MgSO_4$ addition.

When the sludge was excluded and volatile acids were determined by the proposed method there was no difference in the value obtained, after 600 ml. of distillate was recovered, between 200-ml. and 500-ml. sludge samples. If it is assumed until further proof, which is given below, that the recovery of acids by the proposed method is reliable and reproducible and that the value of 4,330 p.p.m. represents the actual amount of volatile acids present in the sludge, then a basis of comparison can be established with the other methods given in Table I. That

TABLE I.—Effect of Type of Distillation, Volume of Sample and Distillate, Addition of $MgSO_4$, and Presence of Sludge

Test No.	Distillation		$MgSO_4$ Addition	Volume of Sludge ml.	Volatile Acids in Distillate[1] (p.p.m.)	
	Type	Sample			1st 150 Ml.	600 Ml.
1	Straight	Sludge mixture	0	200	4,300	—
2	Straight	Sludge mixture	0	50	5,150	—
3	Steam	Sludge mixture	0	200	2,800	4,815
4	Steam	Sludge mixture	0	50	3,120	5,180
5	Steam	Sludge mixture	+	200	4,170	5,470
6	Steam	Sludge mixture	+	50	4,070	5,840
7	Steam	Sludge liquor[2]	+	200	2,995	4,330
8	Steam	Sludge liquor[2]	+	500	—	4,330

[1] As propionic acid.
[2] By proposed method.

the value of 4,300 p.p.m. obtained by straight distillation of 200 ml. of sludge corresponds almost exactly with the value obtained by the proposed method, is merely a coincidence, as there is reason to believe that hydrolysis is an important factor in this type of distillation. It is likely that the actual value obtained is the resultant of two opposing factors—higher yields due to hydrolysis and lower recovery of the original acids present in the sludge. This is partly substantiated by the fact that in steam distillation of sludge mixtures all the 600-ml. distillates gave values higher than the distillation of the same volume of sample in the absence of sludge. Thus, hydrolysis in the presence of sludge was a factor, even when the volume of distilling mixture was kept constant, and recovery with 150 ml. of distillate was not complete, whether or not $MgSO_4$ was added. It appears that to obtain reliable results the solids in the sludge must be excluded, $MgSO_4$ must be added to accelerate the rate of recovery of the acids, and steam distillation and maintenance of the same volume are important. Under these conditions the volume of sample taken does not affect the results. If any of these conditions are not satisfied, variable results are obtained, generally higher than the actual.

A further comparison of the present method and the proposed method of volatile acid determination was made. The determination by the existing method was modified according to Buswell's suggestion (2), and the distillations were made on sludge-free liquors. The original intention was to settle the sludge and decant the supernatant, but due to the viscosity of the sludge sample used the separation was made by centrifuging. If anything, this is a more effective method of removing the sludge.

Two series of experiments were run: (1) the recovery of known added amounts of volatile acids from ripe sludge liquor, and (2) the volatile acid content of stale fresh solids. The present method was run with two different volumes of liquor—namely, 200 ml. and 50 ml. diluted to 200 ml. The results of comparison as obtained by the modi-

TABLE II.—Comparison of the Volatile Acid Recovery by the Proposed and Standard Procedures

Test No.	Sample	Method Used	Vol. Acids Added (meq./l.)			Vol. Acids Found (meq./l.)	Vol. Acids Recovered	
			Acetic	Propionic	Butyric		(meq./l.)	(%)
		(a) Ripe Sludge Substrate						
1	200 ml.[1]	Present	14.25	4.51	17.05	30.30	26.9	75.10
2	200 ml.[1]	Present	0	0	0	3.40	—	—
3	50 ml. dil. to 200 ml.[1]	Present	14.25	4.51	17.05	29.95	28.34	79.10
4	50 ml. dil. to 200 ml.[1]	Present	0	0	0	1.61	—	—
5	—	Proposed	14.25	4.51	17.05	32.93	32.35	90.4
6	—	Proposed	0	0	0	.58	—	—
		(b) Stale Fresh Solids						
1	200 ml.[1]	Present	—	—	—	38.25	—	—
2	50 ml. dil. to 200 ml.[1]	Present	—	—	—	42.15	—	—
3	50 ml. dil. to 200 ml.[2]	Present	—	—	—	55.70	—	—
4	—	Proposed	—	—	—	48.12	—	—

[1] Centrifuged sludge supernatant.
[2] Untreated sludge.

fied present method and the proposed method are given in Table II.

The results indicate that when a total of 35.8 milli-equivalents per liter (meq. per l.) of acetic, butyric, and propionic acids were added to ripe sludge and the volatile acids in the liquor were determined according to the present method, 30.3 meq. per l. were found using 200 ml. of sample. The control sample gave 3.4 meq. per l. of volatile acids. Thus, 26.9 meq. per l. were recovered, or 75.1 per cent of the added amount. Similarly, 79.1 per cent recovery was obtained with a 50-ml. sample. In contrast, the recovery by the proposed method was 90.4 per cent.

It should be noted that the volatile acid from the control, even when the sludge was removed, gave higher values by the present method than by the proposed method. As the material was well digested the differences are smaller than they would have been if the determinations were made on partially digested sludge liquors. It appears that there is some hydrolysis even with sludge-free liquor during straight distillation. In addition, carbon dioxide may contribute to the higher values in the controls by the present method, whereas in the proposed method CO_2 was eliminated by slow addition of acid to adjust the pH to 4.0.

The volatile acid content of the stale fresh solids was 38.25 meq. per l. with 200 ml. of sample, and 42.15 meq. per l. with 50 ml. of sample, as obtained by the modified present method. The same sample of fresh solids gave 55.7 meq. per l. when the sludge was not removed. The proposed method, on the other hand, gave 48.12 meq. per l. These results show that there is hydrolysis when the distillation is made on samples containing sludge and that the modification of running the test on supernatant liquor, proposed by Buswell, reduces the hydrolysis. However, the values obtained by the standard method on sludge-free samples are lower than those obtained by the proposed method. This is due to the fact that complete recovery of the acids is not possible in the 150-ml. distillate collected by the present method and the amount of acids so recovered depends on the nature of the acids and the rate of distillation. Higher recoveries may be expected with a greater ratio of the higher molecular weight acids, such as butyric, than if acetic were the predominating acid present. Therefore, with a mixture of unknown volatile acids the use of a predetermined factor, such as the 0.65 to 0.85 range as proposed by "Standard Methods" (1), can introduce appreciable errors. If an unknown acid mixture consisted mostly of acetic acid the more accurate factor would be 0.65, whereas a factor of 0.85 would be more appropriate if the unknown was composed primarily of butyric acid. An acid mixture containing predominantly butyric acid coupled with the use of a predetermined factor of 0.65 could lead to an error as great as 23 per cent. The acid recovery based on a set volume (150 ml.) and the use of a factor (0.65 to 0.85) is basically unsound. Only complete acid recovery should be the goal. The proposed method of volatile acid recovery is based on 91 per cent acid recovery and thereby eliminates the variations due to the different initial acid composition.

Preliminary Experimentation

In approaching the problem of developing a new procedure for recovery of volatile acids, a study was made of the steam distillation of 3 l. of digesting fresh sewage solids. Also, a similar steam distillation was performed on an artificial mixture of 121.2 meq. of acetic, 49.6 meq. of propionic, and 108.8 meq. of butyric acids, made up to a volume of 3 l. The progressive rate of recovery of the acids in each successive portion of 500 ml. of distillate is plotted in Figure 1. The sludge was not separated from the fresh solids liquor and no $MgSO_4$ was added to

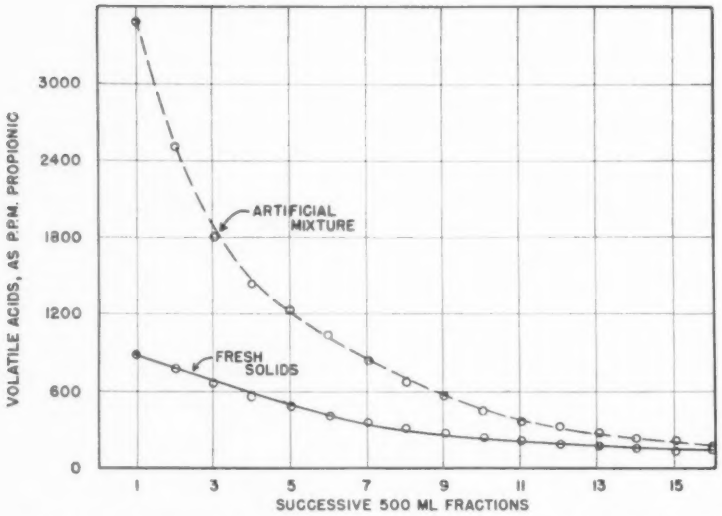

FIGURE 1.—Comparison of the rate of recovery of volatile acids by steam distillation of a sample of sludge and of an artificial mixture of known quantities of acetic, propionic, and butyric acid in distilled water.

either of the two experiments. A total of 8 l. of distillate was recovered. The results show that the maximum amount of volatile acids was obtained in the first 500-ml. portion and each succeeding 500-ml. portion gave lower quantities of acid. A smooth curve is obtained, which becomes almost parallel to the horizontal axis. The last 500-ml. portion of the distillate still contained an appreciable amount (150 p.p.m.) of volatile acids. The results indicate that the p.p.m. recovered in each succeeding portion of distillate is dependent on the amount remaining to be recovered. In both the sludge and artificial mixtures and without $MgSO_4$ a complete recovery is not obtained even after distillation of an 8-l. portion starting with the 3-l. samples. It should be noted that the same trend of recovery was obtained in both mixtures, except that the slope of the artificial mixture curve was greater. Only 74 per cent recovery of the acids added in the artificial mixture was obtained, indicating that in the absence of $MgSO_4$ the rate of recovery is very slow. The direct comparison of both mixtures shows that the rate of recovery is slower in the sludge. This is because distillation in the presence of sludge results in hydrolysis (hence a greater percentage of volatile acid remains at the end of each succeeding fraction) and retardation of distillation of volatile acids.

The next series of experiments were designed to show the effect of the presence and absence of sewage solids and the addition of $MgSO_4$ on the recovery of volatile acids. The results, presented in Figure 2, show conclusive evidence of the hydrolysis of the solids in sewage sludge during either the steam or straight distillations for recovery of the volatile acids. The results obtained from applying the proposed recovery procedure are taken as the control (Figure 2, Curve 4). In this control, only six 100-ml. fractions were required to reach the low of 20 p.p.m. in the final fraction, and a total recovery of 2,806 p.p.m. total volatile

acids expressed as propionic. Three additional steam distillations were carried out on the same fresh solids, from which (a) no solids were removed (Curve 1), (b) all solids were removed by the proposed recovery procedure but no $MgSO_4$ was added (Curve 2), and (c) the liquor was removed (Curve 3).

In the untreated fresh solids sample (Curve 1), a total recovery of 2,611 p.p.m. volatile acids as propionic was obtained from sixteen 100-ml. fractions. It must be kept in mind that the 2,611 p.p.m. recovery, although representing 93 per cent of the control, does not represent the true amount of volatile acids present before the distillation began. Under similar conditions, when the solids were distilled, a total of 632 p.p.m. was obtained from sixteen 100-ml. fractions. Therefore, only 1,979 p.p.m. (or 70.5 per cent of the control) of the original total volatile acid content was recovered from the steam distillation of untreated fresh solids. In the absence of the solids phase the steam distillation of sixteen 100-ml. fractions yielded a total of 2,716 p.p.m. (96.8 per cent of the control) and can be considered an excellent recovery, but the time required to obtain this percentage recovery is so great as to be impractical for analytical work.

A greater volatile acid recovery occurred during the first 6 fractions from the steam distillation when the solids were removed than when the solids were present. On numerous occasions it has been found that a diluted sludge sample will yield slightly higher results initially than an undiluted sludge when subjected to steam distillation. The presence of the solids seems to impair the removal of the volatile acids initially, and consequently the more dilute sample will give a higher yield at the beginning.

To substantiate further the effect of the presence of solids and to link the presentation given in Figure 2 (Curve 5) with that of Table I, a straight distillation was carried out on the solids

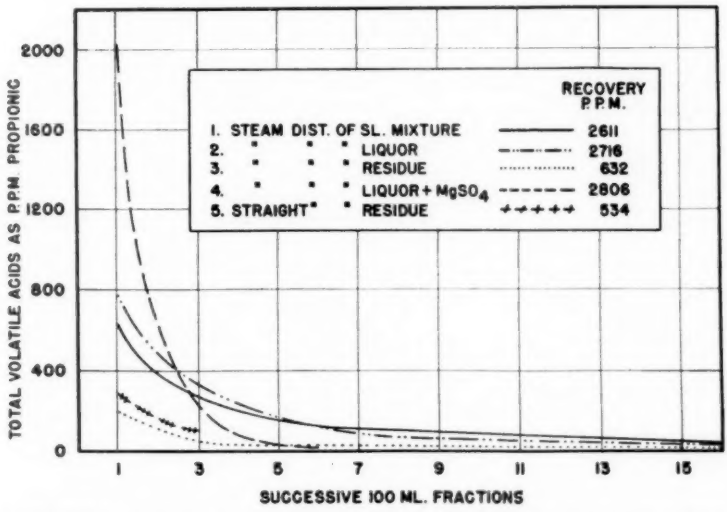

FIGURE 2.—Comparison of determination of volatile acids by steam and straight distillation of a sample of sludge: (a) with and without $MgSO_4$; (b) with and without solids; and (c) of the residue.

removed from a sewage sludge sample by the proposed recovery procedure. For practical reasons, only three 100-ml. fractions could be collected, but a total of 534 p.p.m. volatile acids as propionic (19.0 per cent of the control) was recovered, indicating the large error due to hydrolysis of the solids when the present procedure is followed.

To increase the rate of volatile acids removal from a low value of 74 per cent, obtained with the artificial mixture, to a more reasonable recovery, the procedure of Olmstead, Whitaker,

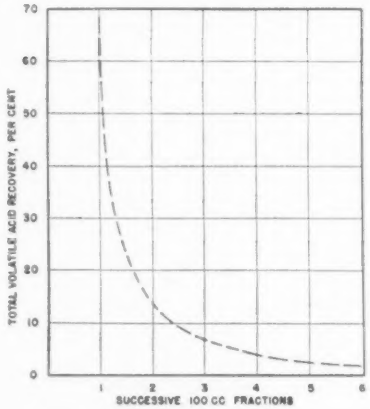

FIGURE 3.—Rate of recovery of known quantities of an artificial mixture of acetic, propionic, and butyric acids in distilled water by steam distillation after saturation with $MgSO_4$.

and Duden (3) (4) was employed. A 150-ml. acidified sample was saturated with $MgSO_4$ and steam distilled, the volume being kept constant. In applying this method to an artificial mixture of 14.18 meq. acetic, 4.54 meq. propionic, and 16.19 meq. butyric acids, markedly improved recovery was obtained. The results are presented in Figure 3. The recovery in all such experiments was between 95 and 98 per cent. These results appeared quite satisfactory, especially in view of previous low volatile acid recoveries.

The first method of removal of sewage solids involved centrifuging, "washing" of sludge, and then centrifuging again, thereby removing the major portion of suspended matter. The combined supernatant was adjusted to pH 3.5, treated with 15 p.p.m. Fe as $FeCl_3$, and flocculated for 10 min. Finally, this mixture was passed through a Buchner funnel containing filter paper covered with a coating of dicalite. A perfectly clear filtrate was obtained at all times. Although excellent results were obtained with this method of solids removal, it was a cumbersome procedure and required approximately 15 hr. for complete recovery of the volatile acids when a 1-l. sample was taken for analysis. The large volume of distillate (usually 3,500 ml.) to be concentrated to 150 ml. was a disadvantage. The new method of solids removal adopted reduced the over-all recovery time to 4 hr. when a 1-l. sample was taken for analysis. A comparison between the older technique and the proposed method of volatile acid recovery is as follows:

Technique Employed	Vol. acids, as Propionic (p.p.m)
New	4,275
New	4,264
Old	4,410

Different samples of the same 4:1 (fresh to ripe) ratio sludge were analyzed by centrifuging and filtration as compared with filtration with Hy-Flo Super Cel. It should be noted that the results using the new technique agreed within 3 per cent with those obtained with the older and longer technique. Therefore, the application of the more rapid method of solids removal did not impair the accuracy of the procedure.

To establish further the validity of this procedure, known amounts of volatile acids were added directly to duplicate sludge samples (Table III) before any treatment was applied. The pro-

TABLE III.—Recovery of Known Amounts of Volatile Acids Added to Seeded Fresh Solids by the Proposed Method of Volatile Acid Determination

Sample		Acid Added (p.p.m.)				Total Acid (meq.)		Total Vol. Acids Found[1] (p.p.m.)	Recovery of Added Acids (%)
No.	Volume (ml.)	Acetic	Propionic	Butyric	Total Volatile	Added	Found		
1	500	0	0	0	0	0	0.457	33.8	—
2	500	0	0	0	0	0	0.562	41.6	—
3	500	852	336	1,424	2,612	34.91	34.90	2,582	98.5
4	500	852	336	1,424	2,612	34.91	35.20	2,605	99.5
5	500	1,704	672	2,848	5,224	69.82	68.40	5,160	97.3
6	500	2,556	1,008	4,272	7,836	104.73	96.21	7,120	91.6
7	500	2,556	1,008	4,272	7,836	104.73	97.10	7,180	92.4
8	250[2]	0	0	0	0	0	0.31	23.3	—
9	1,000	0	0	0	0	0	0.517	38.2	—

[1] As propionic acid.
[2] Diluted to 500 ml.

posed recovery procedure was then carried out. The results show good agreement of the duplicate runs with a total recovery, of the total added acids, of 92 to 98 per cent. In calculating the per cent recovery of added acids in samples 3 to 7, 0.51 meq. was subtracted from each. This is the average found in the control samples, 1 and 2. In samples 8 and 9 the size of sample taken is again shown not to materially affect the total recovery. Therefore, it appears that the volatile acid recovery by the proposed method is of sufficient accuracy.

Discussion

A number of interrelated factors influence the results obtained in determining volatile acids in sewage sludges. As there is no independent method of arriving at the actual volatile acid content, the relative value of the different factors must be arrived at by indirect methods. High values do not necessarily represent actual amounts. In the determination of volatile acids, the following factors have been shown to play an important role in the values obtained: (a) type of distillation, straight vs. steam; (b) volume of sample taken; (c) volume of distillate; (d) separation of solids; and (e) addition of $MgSO_4$.

When the existing procedure is compared with steam distillation of an equal volume of sludge with a recovery of 150 ml. of distillate, the results from straight distillation are higher because of the higher rate of recovery of the acids, due to continuous concentration of the sludge and the mineral acids, and the hydrolysis of the materials in the sludge to volatile acids at higher concentrations obtained during distillation.

Straight distillation is, therefore, eliminated as unsatisfactory. The steam distillation method is preferable to the straight distillation method because the volume of the distilling mixture, and hence the concentration of the mineral acid, can be kept constant, but hydrolysis cannot be completely overcome unless the sludge is separated. Reproducible results, irrespective of the volume of sample, can be obtained only when the sludge-free liquor is steam distilled. For the separation of the sludge, centrifuging, iron treatment of the liquor, and filtration is a satisfactory but time consuming method, because of the larger volumes that have to be filtered and concentrated. This long procedure requires approximately 15 hr. Direct filtration of the iron treated sludge with filter aid on a Buchner funnel greatly

reduces the time required for the determination. This shorter procedure requires approximately 4 hr., increasing with the size of sample taken, if more than 1 l., as a greater volume of filtrate will result from a larger sample. The addition of $MgSO_4$ to the concentrated liquor prior to distillation increases the rate of distillation so that the over-all time consumed is further decreased. It is necessary to concentrate the filtered liquor to reduce the quantity of $MgSO_4$ used to saturate it. In brief, the essentials of the proposed method of removal of solids in order to decrease the hydrolysis include treatment with $FeCl_3$, filtration with filter aid, concentration of the filtrate, and steam distillation of the concentrate after saturation with $MgSO_4$. By this procedure recoveries of known quantities of acetic, butyric, and propionic acids added to sludge have been in excess of 90 per cent.

Summary and Conclusions

This paper has presented the validity of a proposed method of volatile acid recovery from sewage sludge in comparison with the older method as set forth in the "non-standard" section of "Standard Methods" (1). The important interrelated factors that influence the recovery of volatile acids from sewage sludge were discussed: (a) type of distillation, (b) volume of sample taken, (c) volume of distillate, (d) separation of solids, and (e) addition of $MgSO_4$ to hasten the rate of volatile acid recovery.

A practical and reasonably accurate method of recovering 92 to 98 per cent of the volatile acids from sewage solids has been developed. This method involves, essentially, removal of the sewage solids from a sample by coagulation with $FeCl_3$ and the filtration with a filter aid. The filtrate is then concentrated, the pH is adjusted, $MgSO_4$ is added to saturation, and the liquor is steam distilled. The total recovery time for a 1-l. sample is approximately 4 hr., of which at least 50 per cent is required for concentration. In contrast, the present procedure applied to sludge-free liquor can be as much as 25 per cent lower, depending on the ratio of higher to lower molecular weight volatile acids present in the acid mixture.

Addendum

Proposed Volatile Acid Recovery Procedure

(1) Adjust sample of sludge to pH 3.5 with 50 per cent H_2SO_4. Size of sample taken is of no consequence unless the Werkman partition method for identification of the individual acids is to be made, in which case a 200- to 1,000-ml. sample will give the requisite concentration (0.02 to 0.04 N) of volatile acids in the distillate.

(2) Add 100 mgm. Fe (as $FeCl_3$) per liter.

(3) Add 50 gm. Hy-Flo Super Cel filter aid per liter and mix well.

(4) Filter by suction, using 5½-in. Buchner funnel containing a filter paper freshly coated with a thin layer of Hy-Flo Super Cel.

(5) After washing the residue thoroughly 3 or 4 times, remove filtrate and adjust pH to 11.

(6) Evaporate to a volume of 150 ml.

(7) Cool sample in refrigerator to minimize losses of volatile acids upon acidification (step 8).

(8) Adjust pH to 4.0 with 50 per cent H_2SO_4 and add $MgSO_4$ to slight excess of saturation.

(9) Steam distill the first 200 ml. slowly (25 min.), then collect a total of 600 ml. and titrate with 0.1 N NaOH using phenolphthalein.

Acknowledgment

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SELLING MUNICIPAL PROJECTS TO THE PUBLIC *

Although sewage works personnel have day-to-day responsibilities in the conduct of civic affairs of their communities, they have a much more fundamental responsibility in affording guidance and recommendations for the public in the solution of problems having an important bearing on the community's future welfare. "Selling," of course, does not mean just persuading, but connotes educating, informing, and aiding.

An important factor to be borne in mind is the particular "public" being addressed at the moment. Means exist in every American community to sell municipal projects to the voting public. These include such organizations as chambers of commerce, service clubs, and civic associations, as well as the press, the radio, and municipal billing services. In addition, special avenues of approach can be developed by anyone with a little ingenuity and imagination. A check list of some obvious possibilities includes:

1. News releases for press and radio.
2. Statistical summaries of operations with interpretations as to community growth, etc.
3. Progress reports and prospects for future requirements.
4. Photographic or model displays.
5. Informational mailings with utility bills, etc.
6. Billboard displays.
7. Bus and car cards.
8. Movies for presentation at lodge, association, and club meetings.
9. Direct telephone contact by interested individuals.
10. Speaking engagements.

Conditions surrounding each project and each community differ, but a check of these few activities when a project is to be put over will show results and, more importantly, will generally suggest other and more direct and effective means of acquainting the public with the facts of the problem at hand.

* Excerpts from remarks by G. L. Fox, General Manager, San Francisco Chamber of Commerce, at 1949 Annual Meeting, California Sewage Works Association, Stockton, Calif., May 20, 1949.

A STUDY OF B.O.D. WITH TIME AS THE MEASURABLE VARIABLE

By R. S. Ingols

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The biochemical oxygen demand (B.O.D.) test (1) now used to determine the strength of sewage is the result of many years of development. However, in the development of any test, techniques previously in use are frequently discarded either for easier methods or because of the appearance of apparently insurmountable difficulties. Thus, the use of excess nitrates for the B.O.D. test was abandoned in favor of the excess oxygen (dilution) technique, in part because of the relative ease by which the dissolved oxygen may be determined by the Winkler method. As another example, the use of methylene blue to determine the time required for consumption of a limited amount of nitrate oxygen proved to be unsatisfactory because of the dye adsorption by the settleable solids, which interfered with the reading of the color (2). In this latter case, moreover, it was necessary to make frequent color readings in order to obtain a reasonable degree of accuracy; therefore, the use of methylene blue would be limited to relatively large plants having night operators, where readings could be taken on a continuous basis.

However, the use of methylene blue offers the advantage that it is decolorized at an oxidation reduction (redox) potential that lies in the range at which much biological activity occurs. More specifically, its use, assuming that the difficulties previously cited could be overcome, should enable one to obtain data on the nature of the changes in the redox potential of a sewage sample during incubation with oxygen.

As a result of a number of recent technological developments, such as the use of a blender (3) to break up suspended solids, thus eliminating the adsorption of the dye; and of a combination consisting of a photoelectric cell and a recording potentiometer to provide a continuous record of the color intensity of the dye, many of the difficulties formerly associated with the use of methylene blue have been overcome.

Accordingly, it was considered desirable to investigate again the possibility of using methylene blue as an indicator of the time needed for the disappearance of a limited amount of either dissolved or nitrate oxygen from a sewage sample. Inasmuch as this method should give approximate B.O.D. values within 12 to 24 hr. after the incubation starts, assuming that all incubation factors could be made favorable, it was further considered that this procedure might be utilized as the basis of a short-time B.O.D. test in which time, as indicated by a recording potentiometer, would be the measurable variable in the technique.

As will be seen below, the original purpose of this investigation was not successfully accomplished; therefore, the results and conclusions drawn therefrom are presented primarily as a study of the manner in which the redox potential of sewage samples obtained from several sources changed during incubation with either free or combined oxygen.

Experimental Apparatus

A special piece of apparatus was developed to use photoelectric cell-

recording potentiometer combination for determining the color intensity of methylene blue solutions. This device, the general arrangement of which is shown in Figure 1, was fashioned by cutting windows in two small tin cans, after which the cans were soldered together (side to side, with the second can inverted) in such a manner that light could pass through the window of the first one to a photoelectric cell located under the inverted can (Figure 1). The outer window was covered with an A26 Wratten filter to intensify the changes in current flow resulting from small changes in intensity of the blue color. The first can, which was actually the sample holder, was equipped with a removable cap. All interior surfaces were painted black.

This piece of apparatus was normally employed in groups of four, with the leads from each photoelectric cell being connected to one of the four sets of leads of the potentiometer, which was an electronic strip-chart recording galvanometer. Using this arrangement, the color intensity of each sample was recorded at 2-min. intervals; that is, there was a point printed every 0.5-min.

Experimental Procedure

Each sample was placed in a regular dissolved oxygen (D.O.) bottle, after which 1 ml. of 0.5 per cent methylene blue and 1 or 2 ml. of a nitrate solution containing 5 mg. of nitrate oxygen per ml. were added in succession. The bottle was stoppered, then shaken and placed in the sample holder, which was, of course, in front of the photoelectric cell. After the source of light—a 20-watt strip fluorescent lamp—and the recorder were placed in operation, the sample required no further attention until the following day, when the chart was read and the B.O.D. calculated. In-

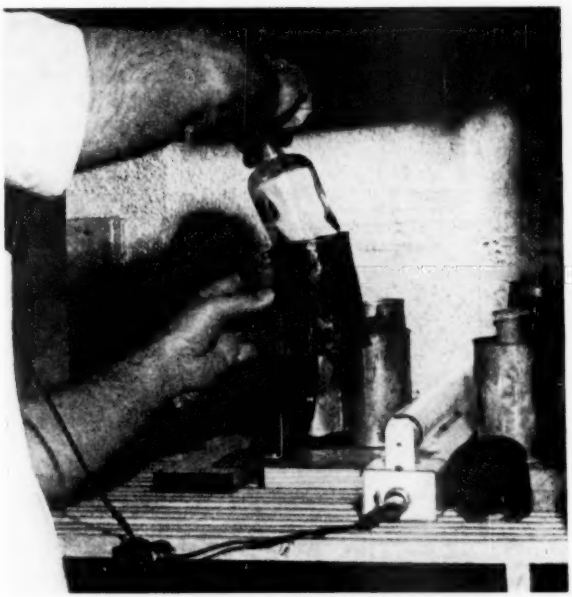

FIGURE 1.—Light source, photoelectric cell, covers, and sample bottle used with the methylene blue studies.

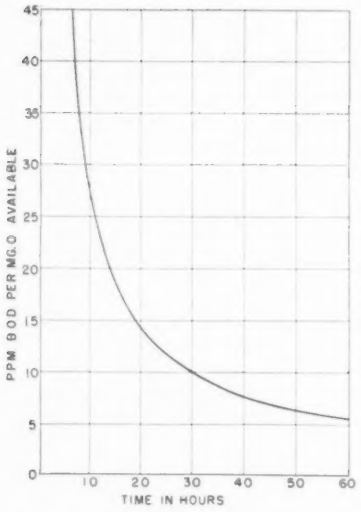

FIGURE 2.—Relationship between time required to decolorize methylene blue and the B.O.D. of a sewage sample, using a 275-ml. bottle and a known concentration of oxygen.

asmuch as fresh sewage may contain some D.O., it was necessary to make up a duplicate sample, which was used in determining the D.O. content of the original sample. Knowing the total amount of oxygen available (nitrate oxygen plus D.O.) and the time required for decolorization of the methylene blue, the B.O.D. was calculated by the relationship (the use of which is described below) between the ultimate B.O.D. and the percentage B.O.D. completed within a given time. For convenience in making this calculation, a chart was drawn so that the B.O.D. could be read directly. The chart (Figure 2) was based on the theoretical B.O.D. curve from the table of relative stability values in the standard method (1) and the average volumes of the D.O. bottles used.

In addition to the methylene blue test, all samples were analyzed to determine their dilution B.O.D. and dichromate oxygen consumed (O.C.) values.

Preliminary Investigations

A number of preliminary investigations, the results of which are described below, were made using samples obtained from one of Atlanta's smaller sewage treatment plants. This particular plant was selected because it received its peak load fairly early in the morning and samples could be obtained with relative ease.

The well-known toxic effect of in-

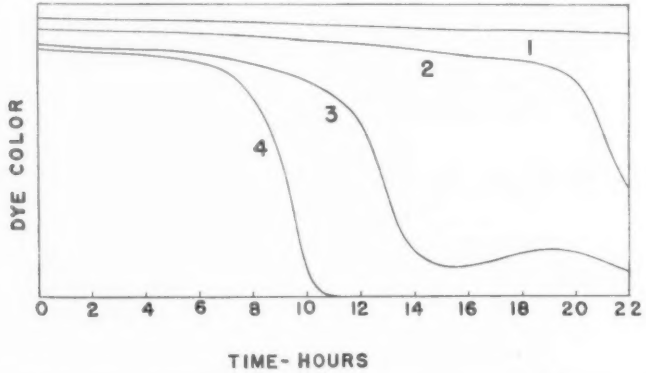

FIGURE 3.—Time required to decolorize a sewage containing different amounts of 0.5 per cent dye solution (resaurin): No. 1, 3.0 ml.; No. 2, 2.0 ml.; No. 3, 1.0 ml.; and No. 4, 0.5 ml.

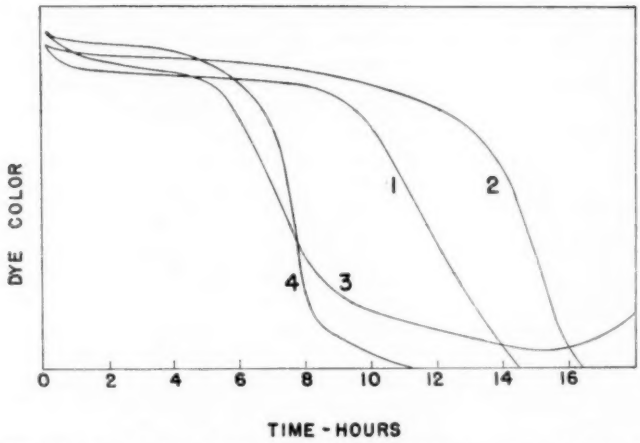

FIGURE 4.—Comparison of the time required to decolorize raw and blended sewages with two dyes: No. 1, raw sewage, 10.9 p.p.m. D.O., using methylene blue; No. 2, raw sewage, 10.9 p.p.m. D.O. using resaurin; No. 3, blended sewage, 14.9 p.p.m. D.O. using methylene blue; and No. 4, blended sewage, 14.9 p.p.m. D.O. using resaurin.

creasing the concentration of the indicator was substantiated as shown by Figure 3. The sample having the shortest decolorization time (Line 4) contained the lowest concentration of dye, whereas the sample containing the highest concentration (Line 1) was not decolorized during the period of study.

The effect of using dissolved oxygen instead of nitrate oxygen on both raw and blended sewage is shown in Figure 4. In this particular test, two dyes, methylene blue and resaurin, were used. The blended sewage (D.O. 14.9 p.p.m.) decolorized both dyes more rapidly than did the raw sewage (D.O. 10.0 p.p.m.). The onset of the

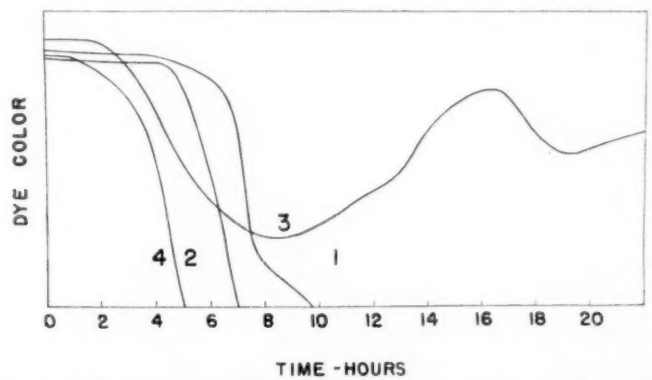

FIGURE 5.—Comparison of different dyes with different sources of oxygen in the same sewage sample: No. 1, sewage plus 18.2 p.p.m. nitrate oxygen, with methylene blue; No. 2, sewage plus 16.6 p.p.m. D.O., with methylene blue; No. 3, sewage plus 16.6 p.p.m. D.O., with resaurin; and No. 4, sewage plus 16.6 p.p.m. nitrate oxygen, with indophenol.

decolorization of both dyes occurred at the same time. The slight increase in the amount of light transmitted during the first few minutes was considered to have been caused by a reduction in the turbidity of the samples.

The effects of using three different dyes and two sources of oxygen were compared. The results (Figure 5) indicate (Line 1) that after the D.O. was utilized, the methylene blue was largely reduced, then reoxidized again as the bacteria attacked the nitrate oxygen, this behavior being typical of the sewage from the plant furnishing this particular sample. These results also indicate that methylene blue was the most suitable of the dyes tested.

An attempt was made by bubbling nitrogen through the sample, to eliminate the necessity for determining D.O.; however, the results obtained were unsatisfactory in that the color of the dye began to disappear immediately, even though nitrate oxygen was present to the extent of 52 p.p.m. In many cases, the color did not reappear.

When septic sewage samples were studied, their behavior was essentially the same as the deaerated samples. Therefore, it was concluded that this test, as set up, would not develop into a routine laboratory procedure capable of handling sewages in all conditions.

Investigations on Second Source of Sewage

The preliminary work previously described was done during dry weather on sewage from a separate sewer system. Inasmuch as it was considered desirable to work with a very fresh sewage, a sample was obtained from a combined sewer system during the rainy season. The methylene blue B.O.D. results obtained with this sewage could not be correlated with either its dilution B.O.D. or its O.C. value. In some instances there was a slow, steady diminution of color (a perceptible amount being present after a period of five days) with no indication of a definite endpoint comparable to those obtained in all of the preliminary

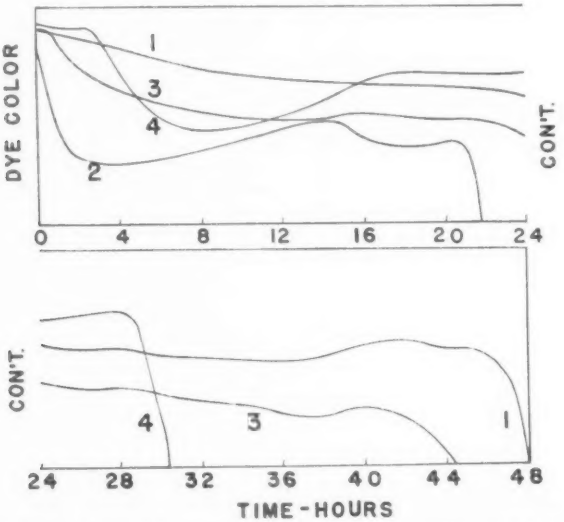

FIGURE 6.—Comparison of four sewages from different sources and having the same oxygen consumed and dilution B.O.D. values.

runs. "Normal" B.O.D. values were obtained with the direct absorption test (Sierp), which has been described by Falk and Rudolfs (4). Accordingly, the persistence of color cannot be attributed to the presence of a toxic factor in the sewage. After similar results were obtained from several runs, several sewages were compared as described subsequently.

Investigations Using Various Sources of Sewage

Four samples were obtained on the same day from four different sewage plants. Oxygen consumed tests were run on each sample, with the stronger ones being diluted so as to have the same concentration of organic matter as the weakest. Biochemical oxygen demand values were also determined by three different methods; viz., dilution, direct, and methylene blue from the final dilution of each sample (Figure 6), settled sewage being used in each instance. The direct B.O.D. values ranged from 77 to 87 p.p.m., the dilution B.O.D. values were all approximately 70 p.p.m., but the methylene blue values varied from 35 to 68 p.p.m. The total O.C. value of 135 p.p.m. indicated that the 5-day B.O.D. values should have been approximately 85 p.p.m. Thus, the correlation between these results and the direct B.O.D. values was satisfactory. The lower dilution B.O.D. values obtained will be discussed in a separate publication. By mere chance the 68 p.p.m. methylene blue B.O.D. value, which was the closest to the 70 p.p.m. dilution B.O.D. value, was obtained on the sewage from the plant furnishing the samples for the preliminary investigations described above, and the lowest methylene blue B.O.D. value was obtained on the second sewage studied.

Inasmuch as nitrates were used as a source of oxygen in obtaining the wide range of methylene blue B.O.D. values referred to, an attempt was made to correlate these B.O.D. values with the period of time required for the onset of nitrification. This attempt was unsuccessful, as all four of the sewage samples began to nitrify on the fourteenth day.

Several attempts were made to study the B.O.D. of glucose and peptone in which sewage comprised 10 to 70 per cent of the total volume. The glucose or peptone, or a combination of the two, was dissolved in dilution water, the dissolved oxygen introduced thereby was determined, and, finally, some nitrate was added. No correlation appeared to exist between the dilution and methylene blue B.O.D. values obtained. The methylene blue B.O.D. values indicated that very little use had been made of the added food in the time required for the dye to be decolorized.

Discussion

Failure to obtain satisfactory correlation between the dilution B.O.D. and the methylene blue B.O.D. values for the same sewage sample was not anticipated; however, two possible explanations will be discussed.

From the negative correlation between the nitrification results and the methylene blue B.O.D. values, it was obvious that no correlation existed between the ability of a sewage sample to initiate nitrification and to utilize nitrate oxygen within a given period of time. This indicates that different groups of organisms are responsible for nitrification and for the methylene blue B.O.D. destruction of the nitrates.

A rational explanation of the different B.O.D. values obtained is apparently dependent on the time required by a given sewage sample to change its redox potential to such a value that the nitrate oxygen is available. The condition of the sewage sample appears to be a factor of some importance in determining this time. Sewages that were obtained from plants having separate sewer systems were fairly stale and gave higher methylene blue B.O.D.

values than sewages obtained from plants having combined systems. At times, the fresh sewage samples did not decolorize the methylene blue within five days.

In general, the condition of a sewage sample exerts the following influence on the results obtained by the use of methylene blue:

1. When very stale sewage is used, the methylene blue is decolorized immediately. Therefore, the time required to utilize the nitrate oxygen cannot be determined, due to the absence of color in the sample.

2. With a sample of old but not yet stale sewage, the dye is quickly decolorized. However, the color returns slowly as the bacteria adjust to the utilization of the nitrate oxygen. This color then disappears entirely after all of the nitrate oxygen is consumed. Good correlation is frequently obtained between dilution and methylene blue B.O.D. values with this type of sample.

3. A somewhat fresher sample normally gives satisfactory results, as the consumption of the nitrate oxygen begins almost immediately and there is only a slight tendency for the methylene blue color to disappear during the initial stages of the incubation.

4. When samples of fresh sewage are used, the lag period between the onset of the test and the consumption of the nitrate oxygen (and thereby of the disappearance of the color) is too long to obtain good correlation between dilution and methylene blue B.O.D. values.

In those cases where good correlation between dilution and methylene blue B.O.D. values was attained, it was necessary that the time required for oxygen reduction be calculated from the onset of the methylene blue decolorization, as the time required for decolorization of the dye was an appreciable percentage of the total time required. This marked variability in the ability of strong sewages to attack nitrates has been also noted by L. C. MacMurray (5), who used as his criterion the production of nitrogen gas during periods as long as three or four days.

Although it appears that methylene blue can be used effectively on biologically treated effluent samples where a long lag period between the onset of incubation and that of decolorization is an indication of the attainment of desirable results—that is, in a plant where the length of the incubation period varies directly with the purification attained—it is evident that where time is to be used in determining the bacterial activity, such a lag period is highly undesirable. In addition, the results cited above indicate that a B.O.D. test in which methylene blue is employed as an indicator for the change in redox potential would be of very limited application; that is, to samples that were "neither too fresh nor too old."

The results of a number of efforts made to overcome some of the difficulties encountered were not very successful. When dissolved oxygen was used instead of nitrate oxygen, it was found that it was necessary to use pure oxygen gas in order to obtain sufficient D.O. in the sample to allow incubation for a reasonable period of time. This required an oxygen tank and a duplicate sample for the determination of the D.O. initially present. Thus, as the use of oxygen did not result in the elimination of all of the difficulties encountered in the use of nitrate oxygen (dilution and methylene blue B.O.D. values could not be correlated), this method did not appear very promising. Attempts to employ both dissolved and nitrate oxygen on the same sample resulted in low methylene blue B.O.D. values, apparently because of the time required to change the redox potential from that present during the use of dissolved oxygen to that required for the use of nitrate oxygen.

With the lag period assuming such

importance in the methylene blue B.O.D. test, it is not surprising that very poor results were obtained in studying the B.O.D. values of pure substances such as peptone or glucose. It has been shown by Ingols and Heukelekian (6) and others that glucose and starch are not used by activated sludge as well at the first dose as during the third or fourth dose. Thus, the use of a short-time B.O.D. test is, even with a heavy innoculum, subject to much greater errors than the present 5-day incubation period because of the lag period in the bacterial activity. This lag period would be lengthened by the presence of any food that is not normally found in a sewage sample.

Conclusions

As a result of the experiments described herein, it is concluded that large differences occur in sewages obtained from various sources, or in sewage obtained from the same source but at different times. These differences are not dependent on the concentration of the organic matter present, and they are not always reflected in the values obtained by the standard (5-day) dilution B.O.D. test.

Summary

The possibilities of developing a short-time B.O.D. test in which time would be the measurable variable in the technique was investigated. A combination of a photoelectric cell and recording potentiometer was used to measure the changes in color intensity of a sewage sample to which a redox potential indicator (methylene blue) has been added. The results obtained were unsatisfactory, apparently due to the excessive time consumed (lag period) during which the bacteria make the necessary changes in the redox potential of the sample, as well as the low initial redox potential of some of the samples, which resulted in the immediate decolorization of the indicator.

Acknowledgment

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THE SHAOYANG, CHINA, NIGHT SOIL FERTILIZER RECLAMATION PLANT

By Ralph Stone

Beverly Hills, Calif.

From January through March, 1947, as part of the sanitary engineering program of the China Office, United Nations Relief and Rehabilitation Administration (UNRRA), a demonstration night soil fertilizer plant was built. More than a year of planning and preparation preceeded start of the actual construction. The work was performed deep in the interior of Central China, at Shaoyang, Hunan, in conjunction with another UNRRA sponsored project named the Agricultural Industries Services (AIS). The Agricultural Industries Services' high purposes were: first, to assist in the relief and rehabilitation of small industries disrupted by the Sino-Japanese War, and secondly, to develop small industries that would be helpful in enriching the economy of a backward agricultural region.

Although the fertilizer plant described was constructed to meet prevailing needs in the Orient, the principles of aerobic and anaerobic digestion are also applicable to the utilization of garbage and sewage sludge. Additional study is needed of the economic factors involved in handling and packaging digested organic fertilizer. Anaerobic digestion provides gas, valuable as fuel, whereas aerobic digestion is quicker. Perhaps a combination of both processes would be advantageous.

Reasons for Plant Construction

The economical and sanitary reclamation of fertilizer values from organic wastes such as sewage, excreta, garbage, and industrial by-products is universally accepted as a desirable conservation practice. The main fertilizer chemical constituents most deficient in soils are nitrogen, phosphate, and potash. In the United States, digested sludge has long been used as an agricultural fertilizer and soil conditioner. Undoubtedly, in the future, as more is learned about the practice of sludge digestion and processing, a better fertilizer product will result for an enlarged market. In the United States, the sanitary aspects of sludge utilization dominate those of fertilizer reclamation. In many countries, however, commercial inorganic fertilizers are not readily available and insanitary organic fertilizers must be used by farmers to maintain the soil fertility. In China, as well as in many other lands, mixed human excrement, called night soil, is a major source of organic fertilizer. As more than 80 per cent of the Chinese people are agrarian, the conservation of night soil fertilizer is a more important item than it would be in the more highly developed industrial societies with operating chemical fertilizer plants.

Unfortunately, however, as a result of the raw excreta polluting the water supply and food of the population, the filth diseases abound. Typhoid fever, cholera, bacilliary and amoebic dysentery, and the worm diseases (such as hookworm) are among the most prevalent illnesses. Nevertheless, because of the prevailing economic and social conditions in China, the health factor is not predominant, and a fertilizer night soil treatment plant must be justified economically by superior reclamation of fertilizer values: in other words, the night soil plant has to be a self-supported undertaking. The factors favorable to the night soil plant

paying its own way through provision of superior fertilizer reclamation are as follows:

1. In the rice growing areas of South and Central China, accumulated excreta is stored by farmers in open field pits or large earthenware jars. Wood ashes, straw, and other waste materials are added to this night soil. An alkaline pH results, so that free ammonia forms and escapes to the atmosphere.

Analyses of night soil samples in a fresh state and after 3 months of field pit storage, indicate that over one half the total nitrogen has been lost. Data for an average of five such tests are:

	Fresh Night Soil	After Pit Storage
Total N (%)	0.62	0.26
NH_3 (%)	0.20	0.14

On the other hand, with properly controlled aerobic and anaerobic bacteriological digestion in a night soil fertilizer plant, these nitrogen losses can be kept below 20 per cent. Thus, the 30 per cent saving in nitrogen over field pit practice represents part of the conservation value of the plant process.

2. Farmers from the countryside obtain their extra night soil by purchasing it either from a middleman in the larger cities, or from a servant of a family in the small villages. The raw excreta is more than 90 per cent water, depending on the amount of urine present. However, a digested and dried sludge contains only about 40 per cent water. Hence, a dried sludge can be transported 6 or more times as cheaply, and obviously with less difficulty than the raw night soil. Similarly, the dried sludge can be stored easily until it is needed for application to the fields and with little fertilizer loss from leaching or evaporation of ammonia.

3. The excess available supplies of night soil exist in the larger cities of China. However, during the winter there is no great demand for the hard-to-transport excreta. Hence, much of it is dumped away and wasted. Also, much of the other organic wastes of the cities are now dumped away. Garbage and street sweepings, together with industrial waste products (such as bones and viscera from abattoirs, rice hulls, leather tanning liquids, etc.) are disposed of in a haphazard manner. By contrast, an organic fertilizer plant operates continuously, and can readily store the final dried fertilizer for use of the farmer when he needs it. Thus, the fully utilized industrial and garbage wastes represent an additional source of organic fertilizer.

4. Other organic fertilizers are employed by the farmers of South and Central China to maintain soil fertility. These fertilizers include peanut cake, green manure, bone meal, garbage, ashes, and animal manures. Chemical analyses for these materials and other fertilizers are summarized in Table I.

TABLE I.—Chemical Analyses of Various Fertilizers (In Percentage by Weight)

Fertilizer	Total Nitrogen, as N	Phosphate, as P_2O_5	Potash, as K_2O
Raw night soil	0.6	0.1–0.12	0.15
Peanut cake	6.0–7.0	1.0–1.5	1.0–1.5
Green manure (from alfalfa and soya)	0.48–0.52	0.08–0.09	0.31–0.73
Bone meal	3.0–4.0	22.0	—
Animal manures	0.2–0.3	0.06–0.03	0.05–0.08
Plant ashes	—	—	2.0–2.5
Ammonium sulfate	20.5	—	—
Calcium superphosphate	—	18.0	—
Potassium sulfate	—	—	48.0
Dried digested fertilizer (aerobic digestion)	3.5±	1.5±	2.2±

Public Health Factors

Reduction of fecal-transmitted diseases is the primary public health problem of contemporary China. Even in Shanghai, the greatest and most modern city in China, by far the largest number of illnesses are the result of fecal-transmitted cholera, typhoid, and dysentery, with 1,865, 1,741, and 1,446 cases reported, re-

spectively, for the annual average between 1934 and 1946. In contrast, diphtheria and cerebrospinal fever are the next most prevalent reported diseases, with 750 and 420 annual cases, respectively.

At Shaoyang, Hunan, a water survey was undertaken of 28 local wells and river watering points, which provide most of the water for the population of 85,000. All the bacteriological samples indicated that coli-aerogenes bacteria were present, and hence that the water sources were of unsatisfactory bacteriological quality. The wells are often uncurbed and have pervious casings. Water is withdrawn by means of privately supplied dirty buckets, and often surface runoff drains directly into the shallow open wells.

A properly operated night soil plant would help control the transmission of the filth diseases. Orderly collection of excreta would provide for proper disposal of the night soil by well-trained collectors. The controlled digestion of this excreta with garbage and other wastes can destroy almost all the pathogenic bacteria present and supply a superior sanitary organic fertilizer.

In anaerobic digestion at normal temperatures, the coli-aerogenes bacteria are destroyed at a rate of 10 to 16 per cent per day (1). For improved destruction of ascaris eggs, and thereby elimination of amoeba and worms, it would be necessary to digest anaerobically at temperatures approaching 150° F.

In good aerobic digestion, however, thermophilic bacteria raise the temperature of the composting mass to between 140° and 150° F. within two days. This temperature drops after an additional 10 days of digestion to between 10° and 120° F. and the digestion continues thusly for 15 more days, after which lower temperatures prevail and fungus growths are active in the process of breaking down the organic matter. The intestinal fauna and flora are largely destroyed by these temperatures and the other unfavorable environmental factors provided by the digestion process. Biological examination of samples of the aerobically digesting excreta and waste material indicated that over 2,000 ascaris eggs are present per gram of the fresh mixture, whereas after one week of aerobic digestion only 100 eggs per gram remained. These latter eggs were largely degenerated or dead.

Aesthetic Values of Plant

One can readily imagine the unsightly and malodorous conditions that result from the haphazard collection of raw excreta and its direct utilization on agricultural produce. A fertilizer plant incorporating a proper collection organization would ameliorate such problems. Concomitantly, the filthy alleys and garbage dumps would be rectified so that rats and flies would not be able to flourish on the waste organic materials. It is estimated that an average Chinese city produces ½ lb. of garbage per day per capita, which contains only 50 per cent digestible organic material. The small quantity of waste matter is the result of the extreme economy of the impoverished Chinese people, wherein everything of value is conserved.

Perhaps the most valuable aesthetic result of a night soil fertilizer plant, would be in the educational benefits that can develop. Farmers would learn about proper composting methods. The inhabitants of the cities and towns would gain a concept of modern sanitary practices. The entire population would thus be helped in terms of additional fertilizer for food, a cleaner environment, and better health.

Construction of Fertilizer Plant

Design

The Shaoyang night soil fertilizer plant was designed to handle the collectable excreta of the population of

85,000 persons, estimated to be 10 short tons per day. To this raw night soil another 20 tons of organic material was to be added, together with any available bone meal and a small quantity of lime. However, because of the unstable political situation, the local government has never been able to deliver daily to the plant more than 25 per cent of the design capacity.

Construction

The plant is located 1,600 ft. from the geographical center of Shaoyang. The Shao River provides the southern boundary for the plant; thus, the construction materials, and later the raw wastes, as well as the final fertilizer products, were easily and economically moved by boat or surface transportation. The site encloses an area of 1.25 acre and was formerly several rice paddies. After construction of a fence, the necessary cut and fill work was done to grade the land. The night soil plant consists of the following components (see Figures 1 and 2):

2 settling basins (96 cu. ft. each) for separation of the urine and feces from the collected night soil.

6 small (325 cu. ft.) aerobic composting pits.

1 large (1,400 cu. ft.) aerobic digestion tank.

2 anaerobic continuous digestion tanks (375 cu. ft. each).

2 anaerobic fill and draw tanks (1,170 cu. ft. each).

1 trickling filter for oxidizing 1,500 g.p.d. of urine (for manufacture of ammonium sulfate).

2 sand and gravel sludge drying beds with tile underdrains (1,600 sq. ft. each).

1 mortar and pestle bone crusher to

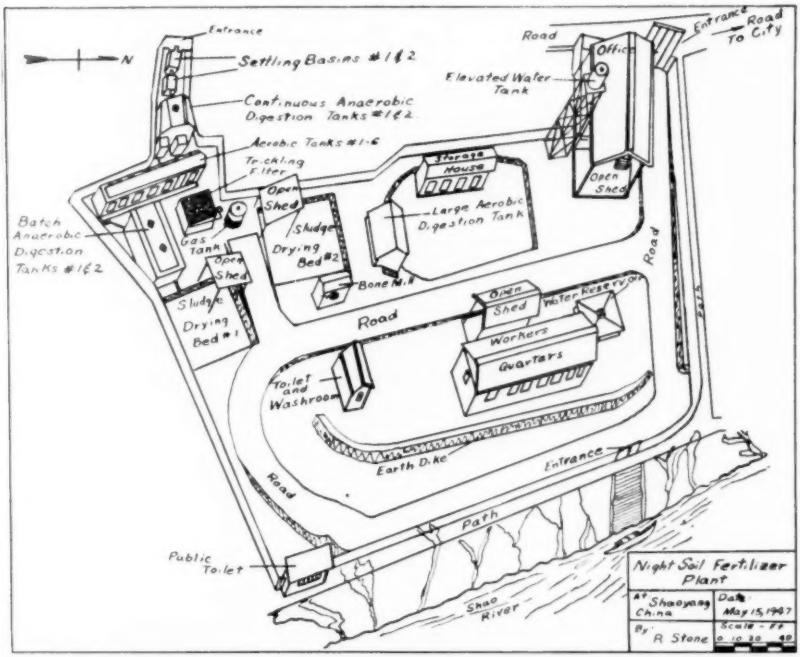

FIGURE 1.—Layout of Shaoyang, China, night soil fertilizer plant.

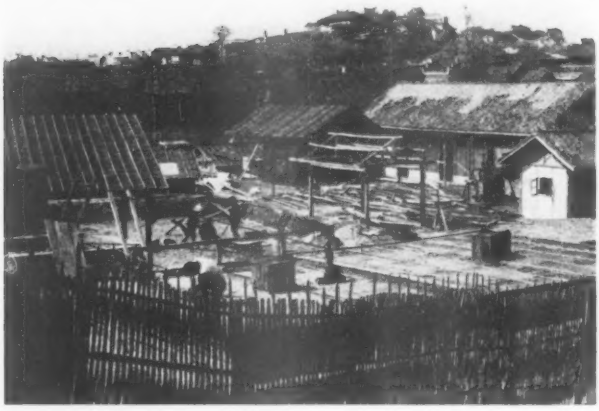

FIGURE 2.—Construction view of night soil fertilizer plant, showing batch anaerobic digestion tanks in foreground.

handle 1,000 lb. of dry bone per day (see Figure 3).

Materials and Workers

The construction materials, insofar as possible, consisted of locally produced limestone, bricks, wood, bamboo, lime, tile, and other items. One of the aims of the project was to demonstrate how native materials can be employed in the development of modern sanitary facilities. Thus, construction costs were kept to a minimum, and the local people could easily duplicate the fertilizer plant works. Native timber and lime mortar were employed wherever structural strength was not the governing factor. A minimum of hard-to-get tarpaper, cement, reinforcing steel, plywood, diaphragm pumps, and piping was used. Special care was taken to build overlapping joints, caulked

FIGURE 3.—Mortar and pestle crusher for preparing bone meal.

with a lime and tung oil preparation in order to have fairly gas-tight digestion tanks. Water glass, manufactured locally, was introduced into the walls of all the tanks in order to help waterproof them. When possible, the tanks were constructed with earth ramparts against the outside walls in order to minimize wall thickness. These ramparts also provided a means of easy access to the tank inlets at the top. Topographic features were partially adopted as earth ramparts, and the tanks were often built adjacent to one another so that they shared a common wall, thus saving on both construction material and labor. The aerobic digestion tanks were provided with built-in-place air vents, false bottoms, and extended wall bricks, all of which assisted in the free circulation of atmospheric oxygen, so as to maintain aerobic digestion.

Over 1,087, 1,036, and 2,496 mandays of carpenter, brick mason, and manual labor, respectively, were employed. Materials used included 54,013 bricks ($12 \times 7 \times 4$ in.), 77 tons of lime, 1,000 pieces of timber (30 ft. long by 8-in. diameter), 105 cu. yd. of gravel, and 39 cu. yd. of sand. One example of the native construction practices encountered was in the carpenter work. The tree logs were purchased and the carpenters on the job sawed the logs by hand to the desired plant dimensions.

The permanent plant operating personnel include a plant manager, a mechanic-foreman, and a dozen workers for collecting the waste material and maintaining the plant operation. In addition, it is normal for Chinese-managed organizations to employ numerous assistants and straw bosses. As the Agricultural Industries Services was and is controlled by Chinese nationals, native labor practices prevail.

Public Toilets

Another part of the Shaoyang sanitation program was the construction of 12 strategically placed public toilets These structures were built of impervious materials and were designed to provide odorless, flyproof, and sanitary service. In addition to being a sanitary convenience to the population, the toilets were a source of night soil collection for the fertilizer plant.

Technical Training Program

Training of technical personnel to operate the fertilizer plant was a necessary portion of the program. Four young engineering college graduates were selected to be engineers in training. To these young men belongs the credit for the materialization of the details of design, construction, and operation of the plant and appurtenances. In addition, several young middle school graduates were trained as mechanics and foremen. Undoubtedly one of the most interesting and worthwhile parts of the sanitation program was the opportunity of working with these enthusiastic technicians.

A small sanitary laboratory was furnished and a competent local chemist performed the many necessary chemical and bacteriological analyses.

Operation of Fertilizer Plant

Manufacture of Ammonium Sulfate

The A.I.S. had initially planned to construct an ammonium sulfate plant utilizing urea as a source of ammonia. A pilot plant was built and tests were run. The project was abandoned when it was found that the fuel costs for evaporation of the NH_3 was prohibitive. The two settling basins and the trickling filter were designed primarily with this project in mind.

Anaerobic Digestion

A great advantage of the anaerobic digestion process is that great quantities of valuable fuel, in the form of methane gas, are produced. Unfortunately, the digestion temperature, unless artificially maintained, is approximately that of the atmosphere and is

insufficient to destroy the amoebic cysts. For this reason, and also because considerable data is available on anaerobic digestion, emphasis was placed on the experimental aspects of aerobic digestion. Essentially the same final fertilizer product is produced by either aerobic or anaerobic digestion.

Aerobic Digestion

It has been stated that the thermophilic bacteria in aerobic digestion produce a temperature of 140° to 150° F. This heat effectively aids in destroying pathogens. The aerobic process produces no disagreeable odors, in contrast to the hydrogen sulphide and other smelly gases evolving in anaerobic digestion. (However, due to the careful plant construction, no odors escaped from the covered anaerobic tanks.)

The raw materials were added in layers to the aerobic digestion tanks by means of the roof inlets. First, the ground and sorted garbage or rice straw was dumped; secondly, a layer of night soil was introduced; and finally, a layer of pulverized bones and a small quantity of lime was added. A mixture by weight of 1 part night soil, 2 parts cellulose waste, and ½ part bone meal was striven for. The important consideration was to obtain a carbon-nitrogen relationship of greater than 20 to 1. With less carbon present there can be nitrogen losses, and bacteriological activity seems slower. Similarly, a pH of 7.1 seems optimum for thermophilic aerobic digestion. Lime was used as the pH control agent. Care was taken to avoid the addition of excess lime, as ammonia gas is liberated readily from basic pH solutions containing ammonium salts. The bottoms of the digestion tanks were constructed with a 5 per cent slope so that the surplus effluent drained into a collection pit for recirculation by pumping or carrying it back to the top of the digesting material. The purpose of this procedure was to maintain an optimum moisture content in the digesting solids, and also to assure that all the nitrogen was extracted from the effluent. In addition, the recirculated fluid acted as a seeding factor to stimulate digestion.

The aerobic digestion period for the first batches of material was 50 to 60 days in the warm (70° F.) humid South-Central China climate. It is believed that with proper seeding material and more experienced operation this digestion time can be safely reduced to 15 to 20 days.

The smaller aerobic tank units operate in a similar manner to the large tank. However, the large tank provides for the volume needed in large scale operation. Also, the digestion was easier to control because of the larger amount of added material.

Digested Sludge

The digested aerobic sludge is a semi-solid mass with an appearance much like humus. The odor is not displeasing. The digested sludge is excavated from the bottom of the tanks and placed on the drying beds in a 6-in. thick layer. The length of time required for drying varies with the sludge composition and the weather. In normal spring sunshine, one week of air drying is sufficient to produce a dry peat-like material. Concrete drying beds would probably be more satisfactory for the aerobic sludge because of the initial semi-solid digested state, and the avoidance of admixture of waste sand in the dried fertilizer. An alternate method of processing the final product is to place the wet digested sludge into a form, where it can be lightly tamped by hand or machine and then placed in an open air rack and allowed to dry as a brick. This dried material (Figure 4) is sold to farmers in place of the raw excreta, and proper directions are supplied for the fertilizer's use. An educational

FIGURE 4.—Finished night soil fertilizer after aerobic digestion and air drying.

campaign was undertaken to acquaint the farmers and townspeople with the significance of the fertilizer plant. The demand for the final fertilizer was greater than the supply; a typical condition in China where there is a fertilizer shortage in most areas. Analyses of the air-dried sludge indicate that the chemical constituents are: total nitrogen, 3.94 per cent; phosphate, as P_2O_5, 1.50 per cent; and potash, as K_2O, 2.27 per cent. The sludge contained 42 per cent moisture, as compared with an average of 96 per cent moisture in samples of raw night soil.

Unit Costs

The cost of operation of the fertilizer plant at capacity, including depreciation, interest on capital, repairs, labor, purchase of raw materials such as lime and bones, collection of the raw night soil, and production and distribution of the product at a slight profit, was calculated at \$0.15 per 100 lb. of finished product. These costs can be reduced in larger-scale operation and with more efficient design and machinery. The chemical fertilizer equivalent costs in China are at least 2 to 3 times the f.o.b. price in the U. S. because of the transportation charges. At a conservative estimate, in China nitrogen is worth \$0.20 per lb.; phosphate, \$0.15; and potash, \$0.10. Hence, the final organic fertilizer equivalent cost would be \$1.27 per 100 lb.

Another advantage of the digested night soil fertilizer is that it has a buffered pH. This helps to stabilize acid soils. Furthermore, the organic fertilizer has the plus values of humus and bacterial enzymes, which stimulate crop production more than a mere chemical analyses can indicate.

Economic Analysis for Fertilizer Plant Operation in Hong Kong

A survey of the night soil disposal methods in Hengyang, Changsha, Shanghai, Canton, and Hong Kong indicates that the householders either dispose of their night soil free of charge or, in the big cities, pay a small charge for the collection service. Unfortunately, in Shaoyang the government was not able to organize a system of complete and free collection. Naturally, this interfered with the operation of the fertilizer plant. The city of

Victoria, Hong Kong, can be utilized as an example of the economic possibilities of a night soil plant. Victoria is chosen as an example because of its relatively stable monetary and political system.

The night soil and garbage for the 880,000 inhabitants is collected by the British Colonial Government. To finance this collection, property owners pay the administration $2.00 per year per floor in each building. The night soil is picked up daily by 1,200 coolies operating in 15 districts. The collected excreta and garbage is transported on boats and utilized in part, although the major portion is dumped. The 10 per cent of the raw night soil that is not wasted is stored in maturation tanks, built during the Japanese occupation, at Castle Peak, New Territory, for 24 days, then sold to the farmers, for $0.17 per 90 lb., f.o.b. The matured night soil is also delivered by truck at a higher price. The garbage that is collected is at times partially employed for filling waste land. Approximately 162 tons of night soil are collected each day; only 25 per cent of the population is sewered. Also, 195 tons of garbage and sweepings is disposed of daily by the sanitation department.

A night soil fertilizer plant for Victoria could be constructed with the following estimated expenses:

Plant construction costs	$500,000
Annual operating costs:	
Depreciation and repair (10%)	$ 50,000
Labor (40 laborers, 1 supt.)	13,200
Power, bones, lime, etc.	20,000
Total annual operating costs	$ 83,200

The daily loading of 162 tons of night soil and 195 tons of garbage, plus the bonemeal and other organic wastes, will shrink in digestion to about 50 tons per day of final organic fertilizer having a minimum content of 2 per cent nitrogen, 1 per cent phosphoric acid as P_2O_5, 0.75 per cent potash as K_2O, and 45 per cent moisture. On the basis of wholesale chemical fertilizer prices, the commercial value of the 18,250 tons of organic fertilizer produced yearly would be $108,200. Deduction of the operating costs leaves an estimated annual profit of $25,000.

On the basis of such analyses for both the new Shaoyang and the proposed Hong Kong fertilizer plants, organic fertilizer can be produced cheaply enough to undersell commercial chemical fertilizer, provided the product is used locally and the excreta can be collected properly. Thus, the Hong Kong night soil fertilizer plant should be able to supply farmers near Hong Kong with a superior organic fertilizer, 3 to 6 times as rich in chemical values as the raw night soil now used, for the same selling price per unit weight. Furthermore, the Colonial Government would be able to cover expenses, while protecting the health and welfare of the entire population. In addition, the plant would provide more available fertilizer and reduce transportation costs by 75 to 80 per cent because of the reduction of non-essential organic matter and the elimination of moisture in the digestion and drying process.

Summary

A demonstration night soil fertilizer plant has been constructed in Shaoyang, China, under UNRRA auspices, to digest mixed human excrement, garbage, straw, bone meal, and waste organic materials from industry, so as to produce a dry, superior, sanitary organic fertilizer.

The most prevalent illnesses in China are the result of pollution of the food and water supply by raw human excrement used as a fertilizer to maintain soil fertility. The aerobic, thermophilic, bacterial digestion process generates natural temperatures as high as 140° to 150° F., which effectively destroys most of the pathogenic organisms present.

The night soil fertilizer plant must pay its own way in terms of fertilizer value, because of present day social and economic conditions in China. Raw night soil cannot be thrown away because of the shortage of fertilizers and the necessity of maintaining crop production. Data are presented that indicate that when the raw excreta is collected by a municipality, the final fertilizer product can be sold more cheaply than commercial inorganic fertilizer.

Acknowledgment

Full acknowledgment is made to the numerous foreign and Chinese engineers and administrators who cooperated in this project. In particular, the following persons were instrumental in the completion of the Shaoyang night soil fertilizer plant: D. S. Abell, chief sanitary engineer, UNRRA China Mission; K. T. Chiang, director, A.I.S., Chinese Government; and H. G. Clement, director, A.I.S., UNRRA.

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REGULATION OF WATER USE FOR AIR-CONDITIONING

Increased use of air-conditioning in homes as well as in office buildings is providing a serious strain on many municipal water systems, according to the American Public Works Association. A corollary problem arises in the over-loading of sewage collection and treatment facilities by the excessive but dilute discharges from these units.

In an effort to conserve water used in the cooling systems, as well as to regulate its discharge into the sewers, some cities have passed ordinances regulating use of water for air-conditioning.

The most common regulatory method is to restrict the discharge of water into the sewer system to a very nominal amount. In Sacramento, Calif., it is unlawful for an establishment to discharge waste water from cooling systems into the sewers at a rate in excess of 1 g.p.m. per foot of frontage of the establishment. Elmira, N. Y., does not allow air-conditioning equipment to be installed unless a means of water disposal other than discharge into the city sewers is provided.

New York City and Philadelphia, Pa., have restrictions on the amount of water that may be used in air-conditioners. All air-conditioning systems in New York using water in excess of 5 g.p.m. must be equipped with a water-conserving unit, such as a recirculating device or a water-cooling tower. Philadelphia requires economizers where maximum water use exceeds 10 cu. ft. per min.

The Washington, D. C., sanitary district will not permit water-cooled air-conditioning equipment to take water from the system at a rate greater than 0.08 g.p.m. per ton of capacity of the cooling unit, or to discharge it at a rate faster than that at which it is taken into the cooling unit.

Other cities regulating use of water for air-conditioning include Champaign and Urbana, Ill., Rochester, N. Y., Richmond, Va., Kensola, Wis., and Reno, Nev.

INTERMITTENT SAND FILTER STUDIES *

By G. R. Grantham, D. L. Emerson, and A. K. Henry

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The Sanitary Research Laboratory at the University of Florida was established principally to determine how conventional sewage treatment methods perform under Florida conditions of higher average temperatures. The plan includes experimentation, as far as possible, with materials native to Florida in order that the cost of sewage treatment to Florida communities will be lower. Present day costs and lack of availability of commonly used materials are cited as reasons why many Florida communities have not undertaken sorely needed sewage treatment facilities.

Purpose of Experiment

The purpose of this part of the general sewage treatment studies is to determine permissible loadings and the corresponding degrees of treatment afforded by intermittent sand filters using native Florida sands as filter media. Properties of some native Florida sands have been described by Emerson (1). These sands meet the recommendations set forth by the A.S.C.E. Committee on Sanitary Engineering (2). Three of these sands have been placed in pilot plant sand filters at two depths and have been dosed at rates from 75,000 to 175,000 g.a.d. for about 12 months. A fourth sand, of somewhat larger size than is commonly used for intermittent sand filters, was also used. This report does not contain results from this latter sand filter due to the fact that, to date, at common loading rates, applied sewage has never completely covered the bed. Dosing of this bed will be continued at increasing rates to determine if, and at what rate, the bed performs satisfactorily.

Test Information

The sand filters are 7.4 ft. by 7.4 ft. (1/800 acre) in plan, and consist of concrete walls with concrete or impervious limerock-asphalt floor (3). Sand of uniform size and character was placed in seven such filters as described in Table I.

TABLE I.—Characteristics of Filter Beds

Sand No.	3C	3C	11D	11D	Mix*	Mix*	11E
Filter Unit No.	10	9	8	11	12	15	14
Effective Size (mm.)	0.25	0.25	0.46	0.44	0.31	0.29	1.04
Uniformity Coeff.	2.24	2.22	2.79	2.78	3.26	3.27	1.70
Depth of Sand (in.)	30	18	30	18	30	18	30

* Mix sand made up of 1 part 3C and 2 parts 11D.

Domestic sewage from a veteran's housing project at the University of Florida was used during the experiment. During periods of low flow, domestic sewage from the main trunk sewer at the University was used to make up the necessary plant flow. The sewage was screened through a mechanically cleaned bar screen with

* A contribution from the Florida Engineering and Industrial Experiment Station, Gainesville, Fla.

¾-in. clear openings, pumped to a flow measuring tank, and settled in either a plain sedimentation tank or an Imhoff tank. For either type of settling tank the detention period was 1.16 hr. in the models, 2 hr. in the prototype. The settled sewage was held in a holding and measuring tank until there was sufficient sewage to load all filters, giving a uniform sewage to be applied to all filters. The maximum holding time was seldom over 30 min. The sewage was stirred before being applied to the filter.

From June 4, 1947, to March 26, 1948, all applications were made with the entire 24-hr. volume loaded once each day. After March 26, 1948, dosages were applied so that half of the 24-hr. volume was loaded in the forenoon and the other half in the late afternoon. The period of the tests is shown in Tables II through VII.

Samples of the applied sewage were taken from the loading flumes during the actual loading. The limitations of collecting representative samples from relatively small and widely varying rates of flow of sewage are recognized. In order to avoid the possible gross errors of intermittent grab sampling, a device was designed to collect each filter effluent continuously, deliver a small portion approximately proportional to the rate of flow into a sample bottle, and discharge the balance. Although this device minimized many sampling errors, it did not eliminate the unavoidable errors due to storage of applied sewage in the bed and to compositing of samples. These errors may account for discrepancies, particularly with the nitrogen balance, in Tables II through VII. From June 4, 1947, to February 1, 1948, samples were taken three times weekly. The B.O.D. test was made on each sample, whereas suspended solids and nitrogen determinations were made on weekly composites preserved with chloroform.

TABLE II.—Test Data for Unit 10: Sand Size, 0.25 mm.; Bed Depth, 30 In.

Loading (g. a. d.)		75,000	100,000	125,000	150,000	175,000	100,000[1]
No. of samples averaged		17	20	16	13	13	12
B. O. D.	applied (p.p.m.)	132	142	142	139	184	127
	applied (lb./acre/day)	82	118	148	174	268	106
	effluent (p.p.m.)	2	5	9	5	12	2
	removal (%)	98.5	96.5	93.6	96.4	93.5	98.5
Susp. sol.	applied (p.p.m.)	98	91	90	116	130	99
	effluent (p.p.m.)	5	10	4	4	5	4
	removal (%)	95	89	95.6	96.5	96.2	96.0
N applied	organic (p.p.m.)	26.6	25.1	28.2	16.5	28.8	19.6
	NH_3 (p.p.m.)	11.0	13.9	14.2	13.3	10.8	17.0
	NO_2 (p.p.m.)	0.006	0.005	0.005	—	0.0044	0.0058
	NO_3 (p.p.m.)	0.18	0.18	0.13	—	0.23	0.15
N effluent	organic (p.p.m.)	0.4	4.5	1.8	1.4	4.0	2.0
	NH_3 (p.p.m.)	0.4	0.9	2.2	2.4	2.9	0.8
	NO_2 (p.p.m.)	0.023	0.013	0.017	—	0.010	0.001
	NO_3 (p.p.m.)	38.8	35.8	22.5	20.8	21.2	33.9
N total	applied (p.p.m.)	37.8	39.0	42.5	29.8	39.8	36.8
	effluent (p.p.m.)	39.6	41.2	26.5	24.6	28.1	36.7
N oxidized (%)		98	87	85	84	76	92
Temperature	sewage (°F.)	82	86–82–78	82–66	79	75	81
	air (°F.)	81	81–83–68	85–53	75	67	76
Test period		6/30–8/9/47	6/4–6/27/47 8/12–8/23/47 3/1–3/16/48	8/26–9/20/47 1/6–1/17/48	9/23–10/24/47	10/28–12/9/47	3/26–6/6/48

[1] Split-flow loading.

TABLE III.—Test Data for Unit 9: Sand Size, 0.25 mm.; Bed Depth, 18 In.

Loading (g. a. d.)		75,000	100,000	125,000	150,000	175,000	100,000[1]
No. of samples averaged		17	20	16	13	12	12
B. O. D.	applied (p.p.m.)	132	142	142	139	181	127
	applied (lb./acre/day)	82	118	148	174	264	106
	effluent (p.p.m.)	7	11	12	7	12	2
	removal (%)	94.7	92.3	91.5	95.0	93.3	98.4
Susp. sol.	applied (p.p.m.)	98	91	90	116	122	99
	effluent (p.p.m.)	5	8	5	4	5	4
	removal (%)	94.9	91.0	94.5	95.8	95.8	96
N applied	organic (p.p.m.)	26.6	25.1	28.2	16.5	23.8	19.6
	NH_3 (p.p.m.)	11.0	13.9	14.2	13.3	11.2	17.0
	NO_2 (p.p.m.)	0.006	0.005	0.005	—	0.0042	0.0058
	NO_3 (p.p.m.)	0.18	0.18	0.13	—	0.20	0.15
N effluent	organic (p.p.m.)	1.7	4.6	4.8	3.2	8.0	0.8
	NH_3 (p.p.m.)	1.6	3.9	5.2	4.3	4.5	1.3
	NO_2 (p.p.m.)	0.046	0.022	0.021	—	0.021	0.009
	NO_3 (p.p.m.)	32.7	22.9	14.0	13.4	12.4	32.4
N total	applied (p.p.m.)	37.8	39.0	42.5	29.8	35.2	36.8
	effluent (p.p.m.)	36.0	31.4	24.0	20.9	24.9	34.5
N oxidized (%)		91	73	58	64	50	94
Temperature	sewage (°F.)	82	86–82–78	82–66	79	75	81
	air (°F.)	81	81–83–68	85–53	75	67	76
Test period		6/30–8/9/47	6/4–6/27/47 8/12–8/23/47 3/1–3/16/48	8/26–9/20/47 1/6–1/17/48	9/23–10/24/47	10/28–12/6/47	3/26–6/6/48

[1] Split-flow loading.

TABLE IV.—Test Data for Unit 8: Sand Size, 0.46 mm.; Bed Depth, 30 In.

Loading (g. a. d.)		75,000	100,000	125,000	150,000	175,000	125,000[1]
No. of samples averaged		16	12	29	13	17	12
B. O. D.	applied (p.p.m.)	116	147	170	137	185	127
	applied (lb./acre/day)	72	122	177	171	270	132
	effluent (p.p.m.)	8.7	17.9	32	12	22	11
	removal (%)	92.5	87.9	81.2	91.2	88.2	91.3
Susp. sol.	applied (p.p.m.)	92	93	98	116	128	99
	effluent (p.p.m.)	8	11	9	4	7	7
	removal (%)	91.3	88.2	90.8	96.5	94.5	93.0
N applied	organic (p.p.m.)	26.3	27.0	30.2	16.5	28.1	19.6
	NH_3 (p.p.m.)	10.4	12.3	16.5	13.3	11.4	17.0
	NO_2 (p.p.m.)	0.0081	0.0033	0.0062	—	0.0037	0.0058
	NO_3 (p.p.m.)	0.17	0.20	0.16	—	0.22	0.15
N effluent	organic (p.p.m.)	2.7	2.8	5.5	4.1	8.4	1.9
	NH_3 (p.p.m.)	2.2	4.4	6.0	5.0	5.4	3.9
	NO_2 (p.p.m.)	0.108	0.25	0.024	—	0.026	0.020
	NO_3 (p.p.m.)	34.7	30.0	15.2	11.0	13.0	28.0
N total	applied (p.p.m.)	36.9	39.5	36.9	29.8	39.7	36.8
	effluent (p.p.m.)	39.7	37.5	26.7	20.1	26.8	32.8
N oxidized (%)		87	80	57	55	49	85
Temperature	sewage (°F.)	82	86–82	82–72	79	75	81
	air (°F.)	81	81–83	85–60	75	67	76
Test period		6/30–8/9/47	6/4–6/28/47 8/12–8/23/47	8/26–9/20/47 1/6–3/16/48	9/23–10/24/47	10/28–12/18/47	3/26–6/6/48

[1] Split-flow loading.

TABLE V.—Test Data for Unit 11: Sand Size, 0.44 mm.; Bed Depth, 18 In.

Loading (g. a. d.)		75,000	100,000	125,000	150,000	175,000	125,000
No. of samples averaged		16	12	29	13	16	12
B. O. D.	applied (p.p.m.)	116	147	170	137	183	127
	applied (lb./acre/day)	72	122	177	171	267	132
	effluent (p.p.m.)	23	36.8	37.5	23.7	27.8	14.3
	removal (%)	88.5	73.9	78.7	82.6	84.5	88.8
Susp. sol.	applied (p.p.m.)	92	93	98	116	129	99
	effluent (p.p.m.)	9	16	13	11	11	9
	removal (%)	90.4	83	87	90.5	91.5	91
N applied	organic (p.p.m.)	26.3	27.0	30.2	16.5	26.2	19.6
	NH_3 (p.p.m.)	10.4	12.3	16.5	13.3	8.2	17.0
	NO_2 (p.p.m.)	0.0061	0.0033	0.0062	—	0.0038	0.0058
	NO_3 (p.p.m.)	0.17	0.20	0.16	—	0.21	0.15
N effluent	organic (p.p.m.)	5.5	6.5	8.2	6.7	9.5	2.8
	NH_3 (p.p.m.)	3.4	6.5	7.7	5.7	4.8	6.4
	NO_2 (p.p.m.)	0.023	0.034	0.0229	—	0.023	0.0383
	NO_3 (p.p.m.)	24.6	19.6	12.1	9.5	11.8	23.4
N total	applied (p.p.m.)	36.9	39.5	36.9	29.8	34.6	36.8
	effluent (p.p.m.)	33.5	32.6	28.0	21.9	26.1	32.6
N oxidized (%)		73	60	43	43	45	72
Temperature	sewage (°F.)	82	86–82	82–72	79	75	81
	air (°F.)	81	81–83	85–60	75	67	76
Test period		6/30–8/9/47	6/4–6/27/47 8/12–8/23/47	8/26–9/20/47 1/6–3/16/48	9/23–10/24/47	10/28–12/6/47	3/26–6/6/48

[1] Split-flow loading.

TABLE VI.—Test Data for Unit 12: Sand Size, 0.31 mm.; Bed Depth, 30 In.

Loading (g. a. d.)		75,000	100,000	125,000	150,000	175,000	100,000[1]
No. of samples averaged		16	20	16	13	16	12
B. O. D.	applied (p.p.m.)	116	142	142	139	183	127
	applied (lb./acre/day)	72	118	148	174	267	132
	effluent (p.p.m.)	3	9	15	11	15	3
	removal (%)	97.5	93.8	89.5	92.0	91.9	97.6
Susp. sol.	applied (p.p.m.)	98	91	90	116	129	99
	effluent (p.p.m.)	5	8	7	4	6	5
	removal (%)	95	91.2	92.2	96.6	95.3	95.0
N applied	organic (p.p.m.)	26.6	25.1	28.2	16.5	26.2	19.6
	NH_3 (p.p.m.)	11.0	13.9	14.2	13.3	8.2	17.0
	NO_2 (p.p.m.)	0.006	0.005	0.005	—	0.0038	0.0058
	NO_3 (p.p.m.)	0.18	0.18	0.13	—	0.21	0.15
N effluent	organic (p.p.m.)	0.9	4.7	3.7	2.3	6.4	1.3
	NH_3 (p.p.m.)	0.6	1.6	2.7	3.0	3.3	0.9
	NO_2 (p.p.m.)	0.037	0.012	0.011	—	0.009	0.008
	NO_3 (p.p.m.)	38.2	20.4	15.2	14.4	18.3	33.5
N total	applied (p.p.m.)	37.8	39.0	42.5	29.8	34.6	36.8
	effluent (p.p.m.)	39.7	36.7	21.6	19.7	28.0	35.7
N oxidized (%)		96	56	70	73	65	94
Temperature	sewage (°F.)	82	86–82–78	82–66	79	75	81
	air (°F.)	81	81–83–68	85–53	75	67	76
Test period		6/30–8/9/47	6/4–6/27/47 8/12–8/23/47 3/1–3/16/48	8/26–9/20/47 1/6–1/17/48	9/23–10/24/47	10/28–12/6/47	3/26–6/6/48

[1] Split-flow loading.

TABLE VII.—Test Data for Unit 15: Sand Size, 0.29 mm.; Bed Depth 18 In.

Loading (g. a. d.)		75,000	100,000	125,000	150,000	175,000	100,000[1]
No. of samples averaged		16	20	16	13	17	12
B. O. D.	applied (p.p.m.)	116	142	142	139	185	127
	applied (lb./acre/day)	72	118	148	174	270	132
	effluent (p.p.m.)	9	17	18	14	21	4
	removal (%)	92.3	88.1	87.4	90.0	88.8	96.9
Susp. sol.	applied (p.p.m.)	98	91	90	116	128	99
	effluent (p.p.m.)	4	8	8	7	7	6
	removal (%)	95.8	91.3	91.1	94.0	94.5	94.0
N applied	organic (p.p.m.)	26.6	25.1	28.2	16.5	28.1	19.6
	NH_3 (p.p.m.)	11.0	13.9	14.2	13.3	11.4	17.0
	NO_2 (p.p.m.)	0.006	0.005	0.005	—	0.0037	0.006
	NO_3 (p.p.m.)	0.18	0.18	0.13	—	0.22	0.15
N effluent	organic (p.p.m.)	1.9	3.4	6.6	3.8	9.0	2.2
	NH_3 (p.p.m.)	1.2	3.7	4.8	4.7	5.2	1.2
	NO_2 (p.p.m.)	0.024	0.028	0.015	—	0.010	0.009
	NO_3 (p.p.m.)	27.5	19.6	13.9	11.2	15.3	31.8
N total	applied (p.p.m.)	37.8	39.0	42.5	29.8	39.7	36.8
	effluent (p.p.m.)	30.6	26.7	25.3	19.7	29.5	35.2
N oxidized (%)		90	73	55	57	52	90
Temperature	sewage (°F.)	82	86–82–78	82–66	79	75	81
	air (°F.)	81	81–83–68	85–53	75	67	76
Test period		6/30–8/9/47	6/4–6/27/47; 8/12–8/23/47; 3/1–3/16/48	8/26–9/20/47; 1/6–1/17/48	9/23–10/24/47	10/28–12/9/47	3/26–6/6/48

[1] Split-flow loading.

From February 1 to June 6, 1948, samples were taken every fifth day. The B.O.D. determinations were made each sampling day, composites of two samples being analyzed for solids and nitrogen. All determinations were made according to standard procedures (4). The Rideal-Stewart modification was used in dissolved oxygen determinations. The results of the tests are shown in Tables II through VII.

During November and December, 1947, at the 175,000-g.a.d. loading rate, Units 9, 10, 12, and 15 began to clog. The schedule of operation of these units during that time is as follows:

Unit	Sand Size (mm.)	Depth (in.)	Date Stopped	Date Started	Date Stopped
10	0.25	30	Nov. 18	Dec. 2	Dec. 20
9	0.25	18	Nov. 17	Dec. 2	Dec. 8
12	0.31	30	Dec. 6	—	—
15	0.29	18	Dec. 10	—	—

Loading of these filters was stopped when the applied sewage from the previous day's loading had not entirely disappeared below the sand surface. Only temporary solution of this clogging problem was afforded by resting the beds. The clogging appeared to be a surface condition only, as microscopic and capillarity observations showed no tendency toward internal clogging. The top 2 in. of sand was removed from the four sand beds and replaced by more of the same sand. As evidenced by records of time of disappearance of applied sewage below the sand surface, some clogging of Units 8 and 11 (effective size 0.45 mm.) was taking place. The record shows that on Unit 8 (30-in. depth) disappearance time was 14, 22, 26, 32, 45, and 53 min., respectively, from December 15 through December 20, whereas on Unit 11 (18-in. depth) disappearance time was 229, 180, 290, 360, and 360 min., respectively, from December 1 through December 5.

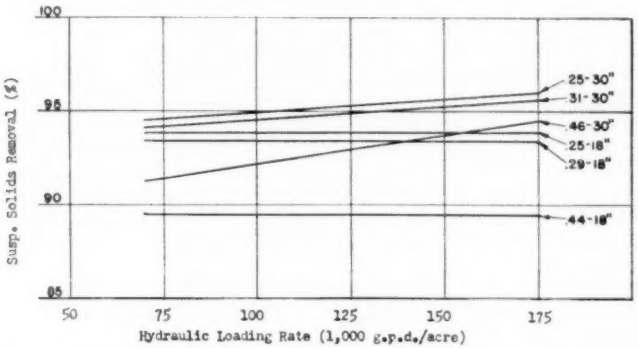

FIGURE 1.—Trend of suspended solids removal as affected by loading rate, sand size, and bed depth.

Discussion of Results

Suspended Solids

Figure 1 is a curve developed from the recorded data to show average per cent removals of suspended solids for each sand size and depth for each loading rate. It can be seen that for practical purposes removal of suspended solids is independent of loading, but is dependent to some extent on sand size and bed depth. Average removals in this test range from 89.5 to 95.8 per cent. Smaller sands and deeper beds give better removals, as would be expected. The additional removals afforded by the 30-in. bed compared to the 18-in. bed are not sufficient to warrant using an additional 12 in. of sand bed depth, particularly with the smaller sand; a difference of 5 per cent removal with a sand size of 0.44 mm. may, in some cases, justify the deeper bed. These removals compare favorably with results obtained (5) at the Roland Park sewage works, Baltimore, Md., where from 1933 to 1938 suspended solids removals averaged 91.7 per cent. No mention of sand size or bed depth was made in this reference.

Biochemical Oxygen Demand

Before B.O.D. removal in these sand filter tests is discussed, it is desirable to point to an important question in the B.O.D. test. The progress of natural purification of polluted waters has been described by Theriault (6). In the natural purification process, nitrogenous B.O.D. does not appear noticeably until after 10 days (at 20° C.) and because of this, the common 5-day B.O.D. (20° C.) test does not measure any nitrogenous B.O.D. Secondary sewage treatment units, in which classification the sand filter belongs, are capable of producing an effluent that is well into the nitrification stage of oxidation, with an apparent flow-through time measured in minutes. Actually, there is a removal of organic matter from the applied waste and retention of this material for a sufficient time to permit a high degree of oxidation (75 to 80 per cent) at the normal oxidation rate.

It is well known that the progress of purification of applied wastes in a sand filter almost invariably proceeds well into the nitrification stage. Data given in Tables II through VII show this to be true in this series of tests. The B.O.D. determination of this treated waste measures not only carbonaceous B.O.D., but also nitrogenous B.O.D. In consequent computation of B.O.D. removals, low results will be found and misleading conclusions will be made as to the progress

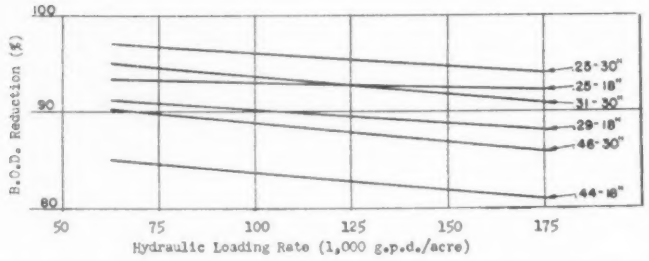

FIGURE 2.—Trend of per cent B.O.D. reduction as affected by loading rate, sand size, and bed depth.

of the carbonaceous B.O.D. stabilization. So little is known about the nitrogenous B.O.D. that it is impossible to compute the proportion of nitrogenous to carbonaceous B.O.D. to give the true picture. In this respect, and concerning only one of the variables of nitrification, that of temperature, Gotaas concludes (7) "The second stage of biochemical oxidations is much more erratic in its course than the first stage, and does not seem to have as consistant a relationship to temperature as the first stage of oxidation."

In view of the above discussion it would appear to be wasteful of time to comment further. However, the curves of Figure 2 show a definite trend in B.O.D. removals with varied load-

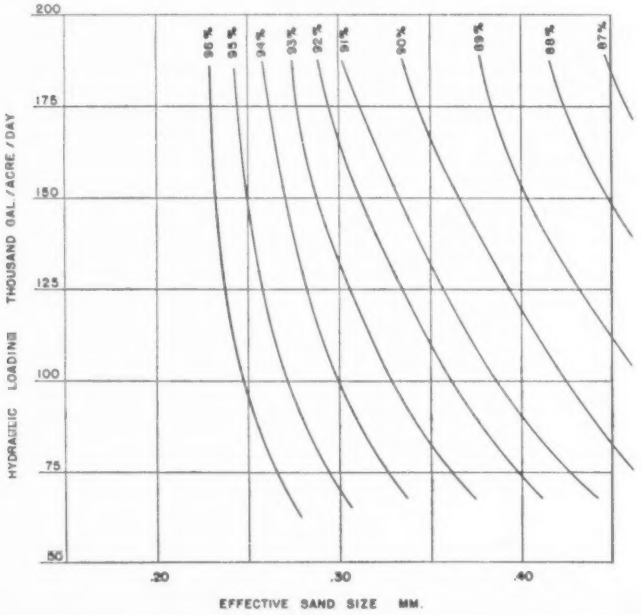

FIGURE 3.—B.O.D. removals as affected by loading rate and sand size for 30-in. depth.

ings, sand sizes, and bed depths. These trends are, as one would expect, toward higher removals of applied B.O.D. using smaller sand sizes and deeper beds, and the removal decreasing slightly with higher loading rates. The curves indicate that at loading rates of 125,000 to 150,000 g.a.d. 93 to 95 per cent removals can be expected on sand of 0.25 mm. size, 89 to 93 per cent removals on 0.30 mm. sand, and 83 to 88 per cent removals on 0.45 mm. sand, when bed depths of 18 to 30 in. are used.

It should be pointed out that B.O.D. results will be dependent, to a considerable extent, on the degree of nitrification. Just as the process of nitrification is dependent on many variables, some of which are not as yet defined, so will the B.O.D. of a nitrified effluent be dependent on those variables. The process of nitrification, judging from the data and from many instances cited in the literature, is at times erratic. As a consequence, reliable results of nitrification and B.O.D. can be obtained only through proper analysis of many data. This fact may account for some variations in the plotted curves of the data.

The data shown in Figure 2 were used to make Figures 3 and 4, which indicate the per cent removals of B.O.D. that may be expected from sand filters with sand sizes between 0.25 mm. and 0.45 mm., and with depths of 30 or 18 in. (and possibly for interpolation for depths between 30 and 18 in.), when operated under conditions of loading and temperature similar to those of the test.

The actual B.O.D. of the effluent produced by sand filtration of wastes is of more significance than the efficiency of the filter in B.O.D. removal. This information provides an estimate of the upper limit of the possible del-

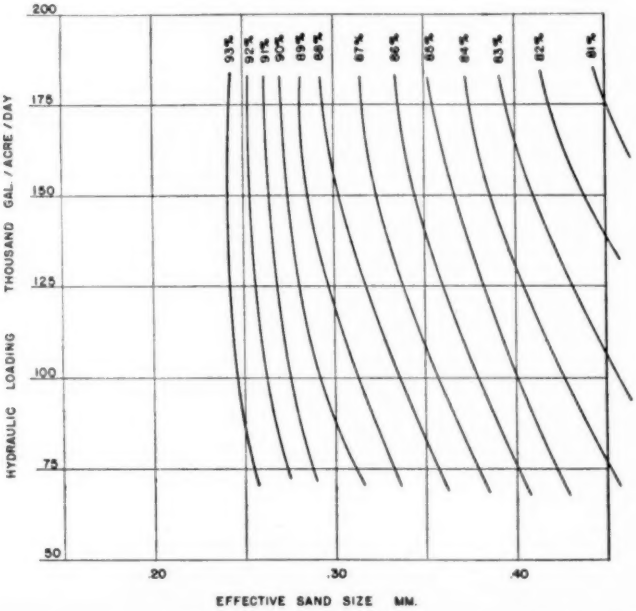

FIGURE 4.—B.O.D. removals as affected by loading rate and sand size for 18-in. depth.

eterious effect of the effluent on the receiving stream or body of water. The curves of Figure 5, developed from the recorded data, show how the effluent B.O.D. is affected by loading, sand size, and bed depth. As would be expected, the effluent B.O.D. increases with loading and sand size, but decreases with deeper beds. This same statement can be made concerning Figure 6, which shows the effluent B.O.D. plotted against applied B.O.D. in pounds per acre per day.

Oxidation of Nitrogen

In order to circumvent the difficulties of the B.O.D. test on nitrified effluents and to obtain a means of measurement of the degree of stabilization of these effluents, the per cent oxidation of applied nitrogen was computed. The method of computing the per cent oxidation was to divide nitrate nitrogen plus 75 per cent of nitrite nitrogen in the effluent by the total nitrogen recovered (8). These data are found in Tables II through VII. The curves of Figure 7 were obtained from data by drawing smooth curves as nearly as possible through the plotted points. From the figure it is seen that the deeper beds and smaller sands afford more complete nitrification. Depth appears to be the predominant factor. The deeper beds of the small sands (0.25 mm. and 0.31 mm.) turned out an effluent that was oxidized 98 and 96 per cent, respectively, at 75,000

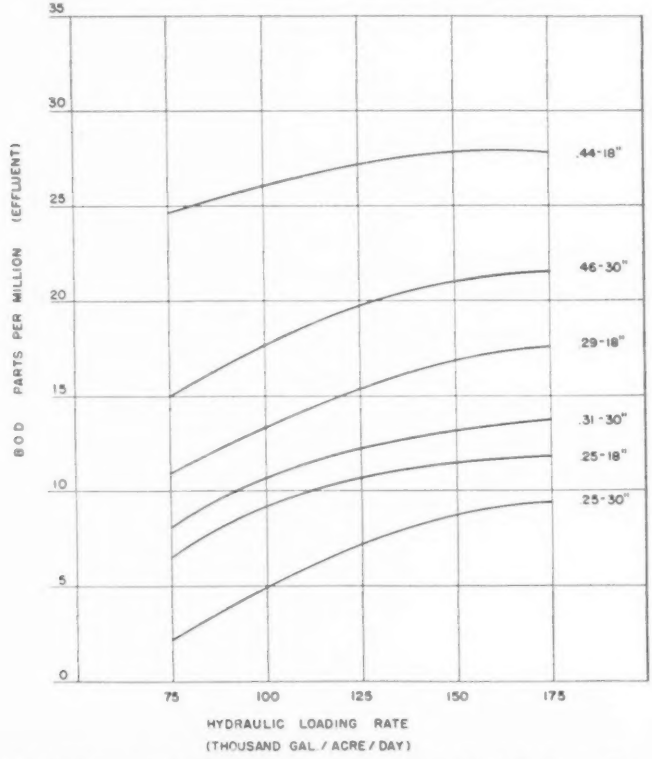

FIGURE 5.—Effect of hydraulic loading rate, sand size, and bed depth on effluent B.O.D.

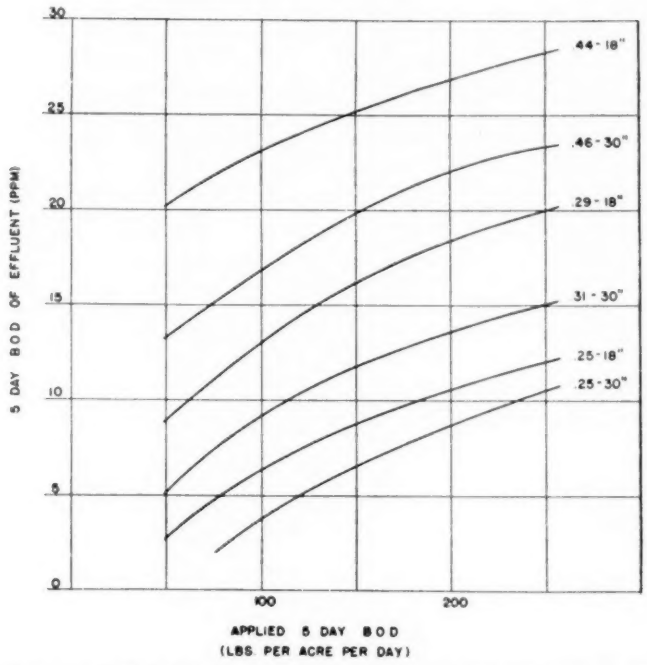

FIGURE 6.—Effect of B.O.D. loading rate, sand size, and bed depth on effluent B.O.D.

g.a.d. loading rate. The per cent oxidation decreases rapidly with increased loadings up to 125,000 g.a.d., then tends to become almost independent of loading at 175,000 g.a.d. In the shallow beds (18 in.), the sand size appears to have less effect on the degree of nitrification than it does in the deeper filters.

Temperature Study

The average air temperatures during the two periods when the beds were being loaded at 125,000 g.a.d. were sufficiently different to allow a study of the effects of temperature on the degree of treatment. Data from which this study is made are given in Table VIII. Comparisons are herein made using average air temperature as a variable because in a sand filter the beds are resting most of the time and are then in contact with the air. The oxidation of material stored in the bed progresses during this resting period. Therefore, the temperature factor in this reaction rate would be governed more nearly by the air temperature. The approximate relation between air temperature and effluent B.O.D. is shown in Figure 8. Data are insufficient to establish more than a trend. Effluent B.O.D. decreases with an increase in temperature, the effect being more pronounced with larger sands and to a limited extent with bed depth. This indicates that with larger sands and more shallow depths more ventilation is obtained, causing the internal bed temperature to follow more closely the variations of air temperature. As only two points are available on each curve of Figure

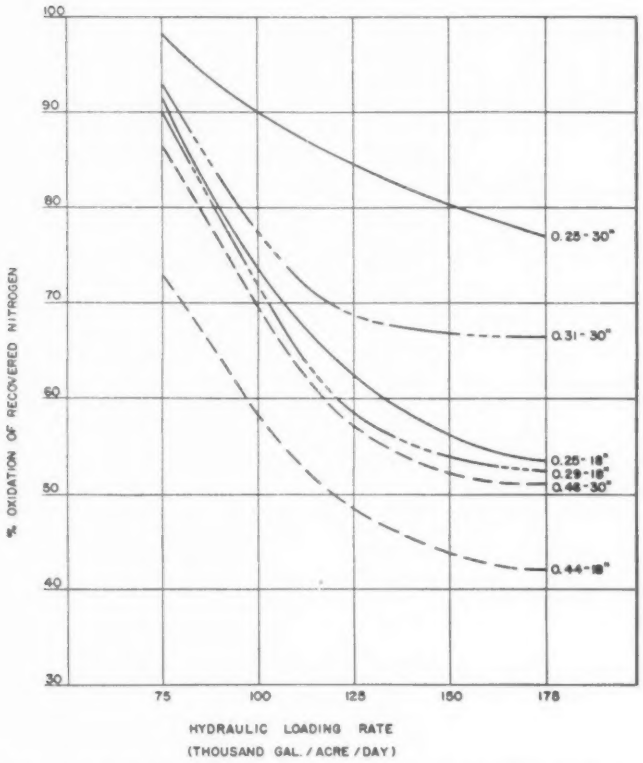

FIGURE 7.—Trend of oxidation of recovered nitrogen as affected by loading rates, sand sizes, and bed depths.

TABLE VIII.—Temperature Study Data (125,000 g. a. d.)

Unit number			8		9		10		11		12		15	
Sand size (mm.)			0.46		0.25		0.25		0.44		0.31		0.29	
Depth of bed (in.)			30		18		30		18		30		18	
Aver. air temp. (°F.)			85	60	85	53	85	53	85	60	85	53	85	53
No. of samples averaged			9	20	9	6	9	6	9	20	9	6	9	6
B. O. D.	applied (p.p.m.)		81	186	81	183	81	183	81	186	81	183	81	183
	effluent (p.p.m.)		9	37	5	17	5	11	10	43	7	23	9	25
	removal (%)		89	80	94	91	94	94	88	77	91	87	89	86
Susp. sol.	applied (p.p.m.)		64	118	64	143	64	143	64	118	64	143	64	118
	effluent (p.p.m.)		4.5	11	3.4	7.6	3	7	5.4	17	5	9.4	4	7
	removal (%)		93	91	94	95	95	95	91	86	92	94	94	94
N	applied	organic (p.p.m.)	16.2	37.2	16.2	52.1	16.2	52.1	16.2	37.2	16.2	52.1	16.2	52.1
		NH_3 (p.p.m.)	11.1	19.3	11.1	20.6	11.1	20.6	11.1	19.3	11.1	20.6	11.1	20.6
		NO_2 (p.p.m.)	0.0028	0.0075	0.0028	0.0076	0.0028	0.0076	0.0028	0.0075	0.0028	0.0076	0.0028	0.0076
		NO_3 (p.p.m.)	0.104	0.184	0.104	0.172	0.104	0.172	0.104	0.184	0.104	0.172	0.104	0.172
	effluent	organic (p.p.m.)	2.2	7.5	2.8	8.8	1.2	3.1	5.1	9.7	1.1	3.8	2.5	14.8
		NH_3 (p.p.m.)	3.5	7.3	3.7	7.4	1.6	3.3	5.3	9.0	1.8	4.8	3.8	6.9
		NO_2 (p.p.m.)	0.027	0.026	0.025	0.0116	0.033	0.014	0.028	0.021	0.034	0.005	0.019	0.010
		NO_3 (p.p.m.)	12.0	14.9	12.6	16.0	19.5	29.0	8.5	13.9	15.0	15.7	11.2	19.3
	total	applied (p.p.m.)	27.4	56.6	27.4	72.9	27.4	72.9	27.4	56.7	27.4	72.9	27.4	72.9
	oxidized	effluent (p.p.m.)	17.7	27.7	19.1	32.2	22.3	35.4	18.9	32.6	17.9	23.3	17.5	41.0
		(%)	68	54	66	50	87	82	45	43	84	67	64	47

8, the relationship between temperature and degree of treatment is not definitely determined.

The effect of temperature on nitrification is also shown in Table VIII. A decrease in the percentage of recovered nitrogen oxidized results as the temperature decreases.

Split Dosing

Data on split flow at 100,000 g.a.d. (Tables II through VII), as compared to the data in the corresponding column of loading rate (single daily dose), shows that in every case more complete removals of suspended solids and of B.O.D., as well as better nitrification, are obtained when the daily volume is applied in so-called split dosing. Comparing these indices of degree of treatment it is seen that 100,000 g.a.d. and 125,000 g.a.d. in split loading gives approximately the same degree of treatment as the 75,000 g.a.d. loading rate

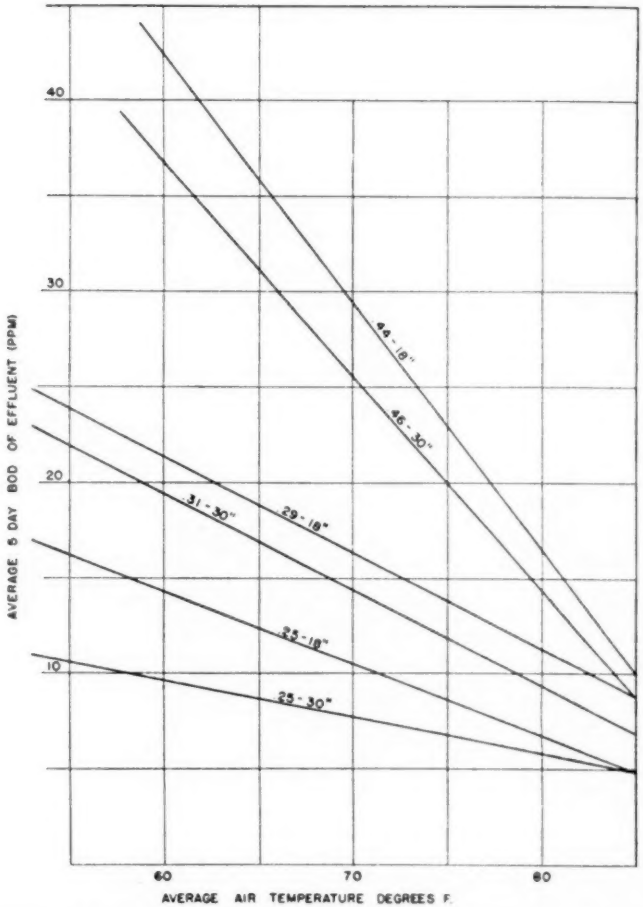

FIGURE 8.—Effect of temperature on effluent B.O.D. for 125,000-g.a.d. rate.

single daily dose. From this it can be concluded—tentatively, at least—that for comparable effluents, filters may be loaded at higher rates if the loading is applied in increments of two or more times daily. Tests on split loading at higher rates are being carried out.

Loading Rates and Sand Size

Operational records show that under loadings of 175,000 g.a.d. beds of the 0.25-mm. and 0.30-mm. size sand became clogged. In addition, records of the time of disappearance of the applied sewage below the surface of the bed show that the largest sand (0.45 mm.) had a tendency to clog at the 175,000 g.a.d. rate. These records also show that at 150,000 g.a.d. the beds containing the 0.25-mm. sand had a tendency to clog, as evidenced by a disappearance time of up to 6 hr. It is believed that 125,000 g.a.d. is the maximum load on 0.25-mm. sand, and 150,000 g.a.d. is the maximum load on 0.30-mm. to 0.45-mm. sands. The applied B.O.D. loading corresponding to these hydraulic loadings are 148 lb. of 5-day B.O.D. per acre per day for 0.25-mm. sands and 174 lb. of 5-day B.O.D. per acre per day for 0.30- to 0.45-mm. sands.

Conclusions

1. The removal of suspended solids is independent of loading rate and temperature, but is, to some extent, dependent on sand size and bed depth. Smaller sands and greater depths afford better removals.

2. The efficiency of sand filters in reduction of B.O.D. of applied waste, when determined by comparison of applied and effluent B.O.D., is low, due to the fact that the effluent is commonly in the second stage of oxidation. The B.O.D. of the effluent is lower, however, when small sands, deeper beds, and lower loading rates are used.

3. Oxidation of recovered nitrogen is more complete with deeper beds, smaller sands, and lower loading rates. The per cent oxidation of recovered nitrogen and effluent B.O.D. values are probably the best means of measuring the degree of purification afforded by sand filters.

4. Within the temperature range of 55° to 85° F. higher air temperature appears to improve sand filter operations as measured by residual B.O.D. values. This effect is more evident in beds of less depth and larger sands, and probably results from air circulation within the bed.

5. On the basis of the present limited data it is tentatively concluded that split dosing permits substantially higher daily loading rates over single daily dosing with comparable purification.

6. Under operating conditions similar to those found in Florida and with settled domestic sewage applied in single daily doses, loading rates up to 125,000 g.a.d. may be employed on sands of 0.25 mm. effective size and up to 150,000 g.a.d. on sands of 0.30 mm. to 0.45 mm. effective size without undue surface clogging or other operating difficulties.

Acknowledgment

Appreciation is due to Professor Earle B. Phelps, who made many valuable suggestions during the test, and whose critical review of this report was of much benefit to the writers. Acknowledgment is also made to Professor W. T. Calaway and to C. H. Edwards, formerly of the Experiment Station staff for much of the analytical work, and to L. H. Ricker, D. E. Barry, Wayne Lee and Z. D. Harrison, student assistants who served as laboratory technicians. Aage Poulsen, plant operator, was responsible for filter loading. Curves in this report were drawn by E. R. Williams, student technician.

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CEMENT-COATED WROUGHT IRON OUTFALL

Extending 1400 ft. out into Monterey Bay, the newest sewer outfall for the city of Watsonville, Calif., was fabricated from ½-in. and ⅜-in. wrought iron plates as a 16-in. diameter pipeline (Figure 1). Fabrication of this line at the site included provisions for overcoming buoyancy and for protection against the abrasive action of shifting sand. This was accomplished by wrapping the 1400 ft. of pipe with steel mesh. The outward end was then covered with gunited sand and cement for 800 ft., the next 600 ft. being coated with cement grout by filling an inclosure made of No. 8 gage steel casing. Watsonville's first line, similarly treated 25 years ago, is reported to be still in good condition. Total length of the new outfall line is 1500 ft., consisting of 700 ft. of pipe with ½-in. wall and 800 ft. with ⅜-in. wall, which required approximately 57 tons of wrought iron plates.

FIGURE 1.—Job fabricated 16-in. diameter outfall consists of wrought iron plates cement coated for abrasion protection.

Industrial Wastes

THE DETERMINATION OF COPPER IN SEWAGE AND INDUSTRIAL WASTES

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General

A thorough chemical literature survey was made for the purpose of developing or adapting a quantitative reproducible method for the determination of micro amounts of copper in sewage and industrial wastes.

The mixed all-dithizone method (1) (2) seemed to possess the greatest possibilities. In this method the copper was extracted by means of dithizone at a pH of 2.3. Any gold, platinum, palladium, silver, mercury, bismuth, or stannous tin also extracts at this pH, but acid digestion oxidizes stannous tin to the stannic state, which will not form a complex with dithizone, and extraction with 2 per cent acidic potassium iodide complexes silver, mercury, and bismuth so that they do not interfere. As gold, platinum, and palladium are so rare, the interference by these elements was not considered.

Three other methods were also studied experimentally, as the manipulations seemed less cumbersome than the dithizone method. These were the sodium stearate (6), benzidine sulfate (7), and sodium diethyldithiocarbamate (8) (9) methods. The first two were not satisfactory, and not enough work was done with the latter method to compare it with the dithizone method.

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Dithizone Method

A. General

The mixed all-dithizone method as worked out by Morrison and Paige (1) seemed to be least affected by interfering ions, as those which did interfere could be removed. No attempt was made to duplicate the work of Morrison and Paige for the recovery of copper from solutions containing interfering metals, for effect of variations in dithizone strength, or for the effect in shaking time, because their work seemed conclusive.

This method was adopted, therefore, for the analysis of copper in sewage and industrial wastes. Several modifications were made in the apparatus used and in manipulations (2). The major change, however, was in selecting malonic acid (3) as a buffer instead of the citric acid phosphate buffer, as the former was more effective in reducing interference due to zinc.

B. Apparatus Used

The apparatus used included a Beckman spectrophotometer; a Fisher electrophotometer with micro attachment; pyrex Erlenmeyer flasks, 300-ml. capacity; glass stoppered volumetric flasks, 50-ml. capacity; and separatory funnels, 125-ml. capacity. All glassware was cleaned with concentrated nitric acid, and was thoroughly rinsed with tap, distilled, and redistilled (metal-free) water.

C. Reagents

Water redistilled in an all-pyrex still was used for making all solutions. Reagents employed were as follows: nitric acid, conc. C.P.; sulfuric acid, conc., C.P.; hydrochloric acid (1 N); ammonium hydroxide, C.P.; LaMotte's thymol blue indicator (acid range); carbon tetrachloride, C.P. redistilled; malonic acid, C.P.; sodium hydroxide, C.P. (pellets); disodium hydrogen phosphate, C.P.; citric acid, C.P.; potassium iodide, C.P.; and sodium thiosulfate (0.1 N).

Buffer reagent, pH 2.25—Dissolved 50 gm. of malonic acid and 7.5 gm. of sodium hydroxide pellets in 250 ml. of redistilled water. This solution was purified by shaking for 5 min., with dithizone, after which the dithizone was removed with successive portions of carbon tetrachloride and the pH was adjusted to 2.25 with 50 per cent sodium hydroxide.

Buffer reagent, pH 2.3—Dissolved 8.3 gm. of anhydrous disodium hydrogen phosphate and 38 gm. of citric acid in redistilled water. This solution was purified by shaking in a separatory funnel with a concentrated solution of dithizone until there was no noticeable change in the color of the dithizone. It was then washed with redistilled carbon tetrachloride, transferred to a 250-ml. volumetric flask, and diluted to volume with redistilled water. Two ml. of this reagent will buffer 25 ml. of water at a pH of 2.3.

Concentrated solution of dithizone (diphenylthiocarbazone), 100 mg. per liter—Dissolved 50 mg. of dithizone in exactly 500 ml. of redistilled carbon tetrachloride. This solution was transferred to a pyrex bottle which had been painted black, and was stored in the refrigerator. Dilute dithizone was made up daily and concentrated dithizone was made up about every three weeks.

Dilute dithizone solution—Fifteen ml. of concentrated dithizone solution was diluted to 200 ml. with redistilled carbon tetrachloride. This was shielded from direct sunlight at all times during the determination.

Acid potassium iodide reagent, 2 per cent—Dissolved 10 gm. of potassium iodide in approximately 250 ml. of redistilled water, acidified with 5 ml. of 1N hydrochloric acid, and added 0.1N sodium thiosulfate, dropwise, to expel any yellow color of free iodine. The solution was washed with dithizone and carbon tetrachloride as in the preparation of the buffer reagent, diluted to 500 ml. with redistilled water, and a few ml. of carbon tetrachloride was added as a preservative. The reagent was stored in the refrigerator and inspected daily for decomposition of the iodide, and adjusted, if necessary, with a drop or two of thiosulfate.

Standard copper solution (stock)—Exactly 0.1000 gm. of sawings from electrolytic copper was weighed into a 50-ml. beaker and dissolved in about 10 ml. of 1:1 nitric acid. After boiling to remove the oxides of nitrogen, the solution was transferred to a 1-l. volumetric flask and made up to volume with redistilled water. One ml. of this solution contained 0.1 mg. of copper.

A working standard copper solution was made by diluting 5 ml. of the stock solution to 500 ml., in a volumetric flask, with redistilled water.

D. Recommended Procedure for Sewage and Industrial Wastes

The recommended procedure for determining 0–10 p.p.m. copper in sewage and industrial wastes is as follows:

Stir the sample by means of a mechanical stirrer and at the same time syphon a portion of the sewage or industrial waste containing less than 0.35 mg. of copper into a 300-ml. Erlenmeyer flask. Add 5 ml. of concentrated nitric acid, evaporate to approximately one-half the original volume, cool, add 5 ml. of concentrated sulfuric acid, evaporate to fumes, cool, add 20

ml. of redistilled water, and evaporate once more to fumes. Cool, add 20 ml. of redistilled water and bring to fumes again. At the same time take a blank containing the acids through the same procedure. Transfer samples to 50-ml. volumetric flasks, cool to room temperature, and make up to volume. Mix thoroughly. Pipette a suitable aliquot of the sample solution (containing less than 7 micrograms of copper) into a 125-ml. separatory funnel. Dilute to 25-ml. volume with redistilled water, add 3 drops of thymol blue indicator, and adjust with concentrated ammonium hydroxide to a peach color (pH approximately 2.3). Add 2 ml. of malonic acid buffer solution and 20 ml. of freshly prepared dilute dithizone solution. Shake for 10 min. Pour off the aqueous layer, add 10 ml. of potassium iodide solution, and shake for 2 min. Transfer the carbon tetrachloride portion to a spectrophotometer or electrophotometer cell previously dried with redistilled acetone and rinsed with a carbon tetrachloride portion of the sample. Determine the optical density of the solution in the spectrophotometer at 510 millimicrons, using as a blank a solution which has been treated in the same manner as the sample, set at zero optical density. If the Fisher electrophotometer is used, the reading is taken on the A scale of the electrophotometer using a green filter (No. 525). The instrument is set at zero optical density with redistilled carbon tetrachloride and the blank is read and is then subtracted from that of the unknown. The concentration of copper is determined from a previously prepared calibration curve.

E. Preparation of Transmission Curve

Standards containing 0.000 to 0.010 mg. of copper were prepared and the transmission was measured at various wave-lengths. A transmission curve was drawn and 510 millimicrons was

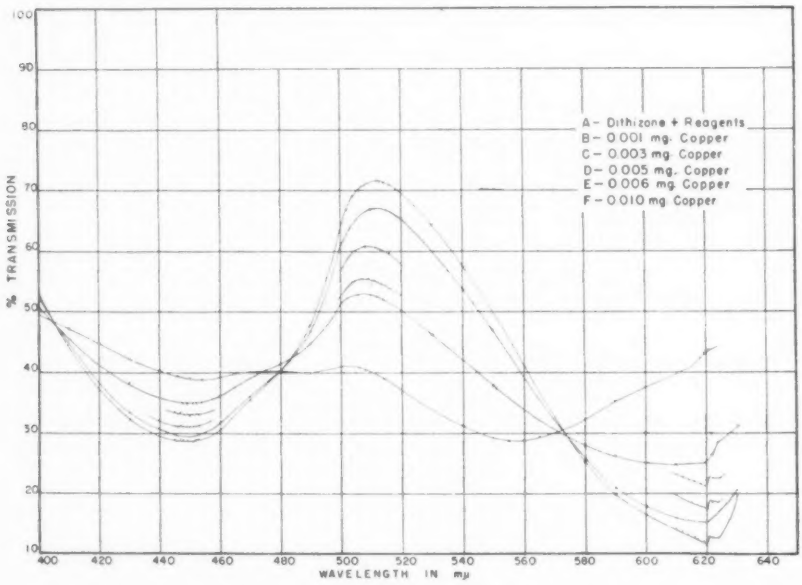
% TRANSMISSION
WAVELENGTH IN mμ
A – Dithizone + Reagents
B – 0.001 mg. Copper
C – 0.003 mg. Copper
D – 0.005 mg. Copper
E – 0.006 mg. Copper
F – 0.010 mg. Copper

FIGURE 1.—Transmission curves of copper-dithizone solutions for Beckman spectrophotometer.

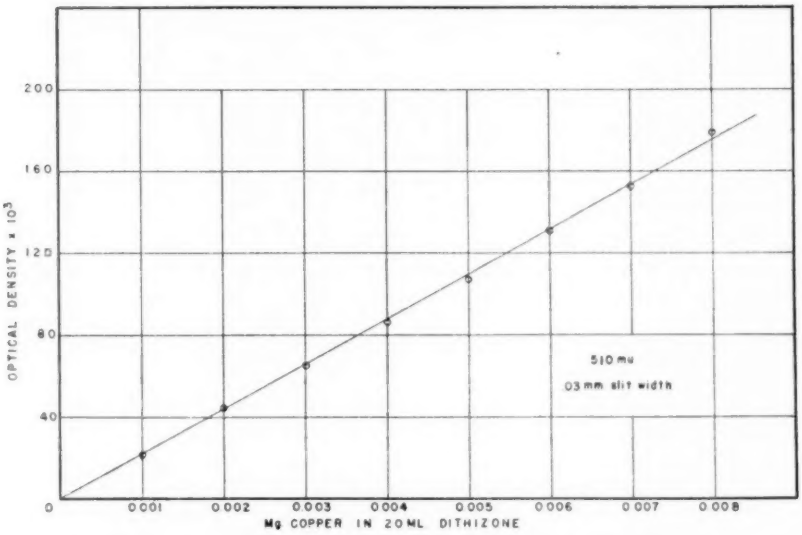

FIGURE 2.—Calibration curve for determination of copper with dithizone by Beckman spectrophotometer.

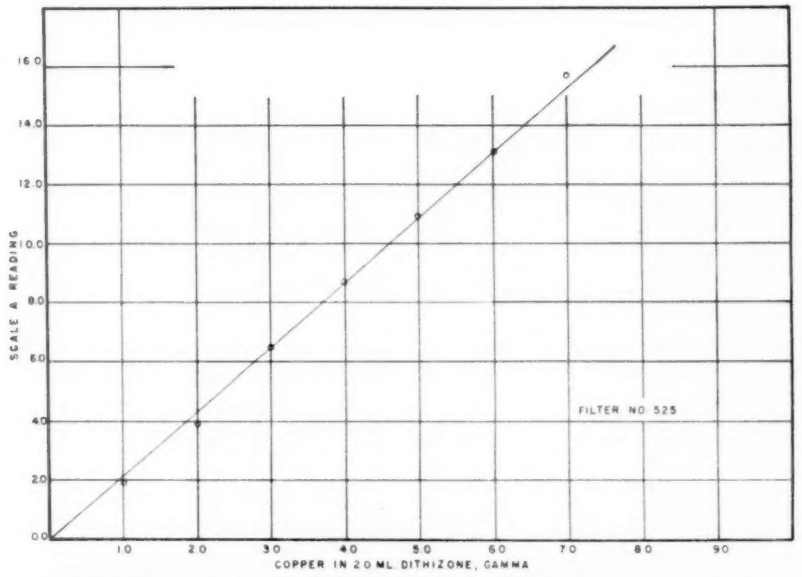

FIGURE 3.—Calibration curve for determination of copper with dithizone by Fisher electrophotometer.

chosen as the optimum wave-length (see Figure 1).

F. Preparation of Calibration Curve

1-, 2-, 3-, 4-, 5-, 6-, and 7-ml. quantities of copper standard (containing 1 microgram of copper per ml.) were pipetted into 7 separatory funnels, with an eighth serving as a blank. Five ml. of 10 per cent sulfuric acid was added to each, and the volume made up to 25 ml. The procedure was continued as with the unknown sample (see Figures 2 and 3).

G. Experimental Work

Samples were run to check the recovery of known amounts of copper added to settled sewage. The sewage was made acidic to methyl orange with concentrated sulfuric acid, filtered through cotton, and placed in the 20° C. incubator for a few hours to bring to constant temperature. Fifty-ml. samples of the sewage were then pipetted into 250-ml. Erlenmeyer flasks, which had previously been washed with nitric acid, rinsed with tap water, distilled water, and finally with double distilled water. Copper in amounts ranging from 10 to 70 gamma * was added to each 50-ml. sewage sample. To each was added 10 ml. of concentrated sulfuric acid and 10 ml. of concentrated nitric acid. Several 2-in. lengths of capillary tubing were added to minimize bumping. Samples were evaporated to fumes of sulfur trioxide over a free flame. Even with the capillaries, severe bumping took place. Another objection to the capillaries became evident when the samples were transferred to volumetric flasks. It was difficult to remove the acid solution from the capillaries and some of the losses observed may have been due to this. After the samples were taken to fumes they were cooled and 25 ml. of redistilled water was added. This time, however, they were placed on an asbestos sheet on the hot plate. It took a much longer time to take the samples to fumes, but no bumping was noticed. After cooling, a second 25-ml. portion of redistilled water was added and the samples again taken to fumes. A blank of 50 ml. of distilled water was carried through the same procedure as the other samples. After cooling, all samples were transferred to 50-ml. volumetric flasks and made up to volume with redistilled water. Ten-ml. samples of sewage alone and 5-ml. samples of sewage plus copper were taken for analysis. Corresponding amounts of the blank were taken for each run. Samples were run according to the recommended procedure previously given. The results obtained were low and part of the copper loss was thought to be mechanical rather than chemical.

Into 300-ml. Kjeldahl flasks, 50-ml. samples of the same filtered sewage used above were pipetted. In another Kjeldahl flask 50 ml. of redistilled water was placed for a blank. To each sewage sample 20 gamma of copper were added, followed by 10 ml. of sulfuric acid and 10 ml. of nitric acid. The samples were then digested and taken to fumes on the Kjeldahl digestion rack. Bumping occurred, but no loss of sample was noticed. The samples were treated as before and results were again low.

Five 50-ml. samples of the same sewage were pipetted into 250-ml. Erlenmeyer flasks and 50 ml. of redistilled water was placed in a sixth flask for a blank. To each sewage sample 50 gamma of copper was added. After adding 10 ml. of sulfuric acid and 10 ml. of nitric acid, the samples were placed on an asbestos sheet on the hot plate. The samples were treated as before and the results were high.

A new sample of sewage was obtained, acidified, and filtered; samples were taken as before for further recovery tests. Erlenmeyer flasks were used and the samples digested on the hot plate. The method used was the

* 1 gamma = 0.001 mg.

same as given above except for a slight change in the blank. The first 50 ml. of redistilled water was omitted (as it was not added to the sample) and 10 ml. of sulfuric acid and 10 ml. of nitric acid only were added to the blank flask. After taking to fumes, 25 ml. of redistilled water was added, the solution brought to fumes, a second 25-ml. portion of redistilled water added, and the blank again fumed. These results were somewhat erratic.

In another set of determinations on the recovery of copper from sewage the following procedure was used: A sample of sewage was allowed to settle for about 15 min. The sewage was then poured into a pyrex bottle, thus leaving only the larger and heavier solids behind. Six 50-ml. samples of sewage were pipetted into 250-ml. Erlenmeyer flasks. Ten ml. of concentrated sulfuric acid and 10 ml. of concentrated nitric acid were added. To two of the samples, 50 gamma of copper was added; to two others, 10 gamma of copper; and to the last two, no copper. Digestion and extraction was carried out as above.

The same samples were run 18 to 20 days later to see if a change had occurred over this period of time. Recovery results were fairly satisfactory for the higher range (3 to 7 gamma). The length of time the sample was kept in the volumetric flask after having been made up to volume seemed to affect the amount of copper recovered. The effect was greater in the lower range (1 to 3 gamma) than in the higher range (3 to 7 gamma).

Copper determinations were made on a single sewage sample after standing in the refrigerator 1, 2, 3, and 5 days. Four to six 100-ml. samples of sewage were taken on the respective days. These samples were digested as before, transferred to 50-ml. volumetric flasks, and made up to volume. Each chemist took two samples through the procedure to determine the effect of individual techniques. For the first two days, each chemist fumed a separate blank, but for the remainder of the time a common blank was used. The results, given in Table I, varied from 0.17 to 0.27 p.p.m. The standard deviation, σ, was 0.0348 p.p.m. (see Table I).

TABLE I.—Copper Determined in Same Sewage Sample on Successive Days

Det. No.[1]	Date Sample[2] Fumed	Anal. Date	Aliquot (ml.)	Optical Density	Copper (gamma)	Copper (p.p.m.)
1	6-22	6-23	10.0	0.106	4.89	0.24
1	6-22	6-24	10.0	0.101	4.66	0.23
2	6-22	6-23	10.0	0.112	5.16	0.26
3	6-22	6-23	10.0	0.072	3.32	0.17
3	6-22	6-24	10.0	0.107	4.93	0.25
4	6-22	6-23	10.0	0.073	3.37	0.17
5	6-23	6-24	10.0	0.101	4.66	0.23
6	6-23	6-24	10.0	0.106	4.89	0.24
7	6-23	6-24	10.0	0.104	4.79	0.24
9	6-25	6-26	10.0	0.073[3]	3.37	0.17
9	6-25	6-26	10.0	0.119[3]	5.49	0.27
11	6-25	6-26	10.0	0.074[3]	3.41	0.17
13	6-26	6-28	5.0[4]	0.056	2.58	0.26
13	6-26	6-28	10.0	0.094	4.33	0.22
14	6-26	6-28	5.0[4]	0.042	1.94	0.19
14	6-26	6-28	10.0	0.087	4.01	0.20
15	6-26	6-28	10.0	0.092	4.24	0.21
Σ	—	—	—	—	74.56	3.72
Avg.	—	—	—	—	4.386	0.219
Standard deviation, σ					0.7070	0.0348

[1] All the same sewage sample, but designated so as to differentiate separate fumings.
[2] Sample of sewage collected June 22, 1948.
[3] Only one 20-ml. portion of water added.
[4] Sample considered as 10 ml. and proper corrections made for computing deviations.

To remove the interference due to zinc, malonic acid buffer was used in place of citric acid phosphate. Experiments were made to compare the buffering effects of malonic acid with those of citric acid phosphate. To test the buffer, three drops of thymol blue indicator were added to 25 ml. of distilled water, and different amounts of concentrated ammonium hydroxide were added. The pH was noted, 2 ml. of the buffer was added, and the pH

TABLE II.—Buffering Effect of Malonic Acid Vs. Citric Acid Phosphate Solution

Color of Solution	Addition of Malonic Acid Buffer		Addition of Citric Acid Phosphate	
	pH Before	pH After	pH Before	pH After
Pink	1.85	1.95	1.85	2.0
Peach	2.2	2.25	2.15	2.3
Yellow	7.6	2.65	7.5	3.1
Light blue	8.65	3.35	8.2	4.0

again read. The results are shown in Table II.

To see if the malonic acid buffer had any effect on the position of the points on the calibration curve, standards were made using this buffer instead of the citric acid phosphate solution. The results are given in Table III. With the 3 gamma standards the mean value for four readings was 0.066 as against 0.065, the value used for plotting the standard curve. With the 6 gamma standards the mean value for four readings was 0.134 as against 0.132, the value used for plotting the standard curve.

These values checked sufficiently well so that a restandardization was not considered necessary.

An experiment was performed to see if the heat generated during neutralization decomposed the dithizone giving erratic results. Dithizone was added to four samples; two that had been cooled after neutralization and two that had not been cooled. The amount of copper recovered in both cases was almost the same showing that the heat generated during neutralization did not seem to affect the recovery. The results are shown in Table IV.

TABLE III.—Readings for Standards Using Malonic Acid Buffer

Copper (gamma)	pH	Malonic Acid Buffer (ml.)	Optical Density	
			Run	Mean
3.00	2.35	1.0	0.064	0.066
3.00	4.9	1.0	0.066[1]	
3.00	2.25	1.0	0.069	
3.00	2.0	1.0	0.065	
6.00	3.1	2.0	0.135	0.134
6.00	2.25	2.0	0.132	
6.00	2.5	2.0	0.135	
6.00	2.35	2.0	0.135	

[1] Shaken with 5 ml. double distilled water and acidified with 2 drops of 10 per cent sulfuric acid after the original solution was poured off.

TABLE IV.—Effect of Heat

Copper (gamma)	Optical Density	
	Hot Sample	Cold Sample
6	0.130	0.131
6	0.131	0.135

Another set of copper determinations was made on the sample of raw sewage using the malonic acid buffer; excellent results were obtained. The results varied from 0.21 to 0.27 p.p.m. (see Table V). The average of the sixteen results was 4.59 gamma, or 0.231 p.p.m. The standard deviation was 0.3226 gamma, or 0.0175 p.p.m. The standard deviation, σ, was obtained from the usual formula (5):

$$\sigma = \sqrt{\frac{\Sigma x^2}{n-1}}$$

TABLE V.—Copper in Raw Sewage

Det. No.	Aliquot (ml.)	pH	Copper Content	
			(gamma)	(p.p.m.)
1	10	—	5.35	0.27
2	10	—	4.33	0.22
3	10	—	4.24	0.21
4	10	—	5.30	0.27
5	10	2.35	4.56	0.23
5A[1]	10	2.65	4.70	0.24
6	10	2.25	4.33	0.22
6A[1]	10	2.3	4.24	0.21
7	10	2.3	4.66	0.23
7A[1]	10	2.55	4.52	0.23
8	10	2.3	4.70	0.24
8A[1]	10	2.25	4.61	0.23
9	10	2.1	4.56	0.23
10	10	2.05	4.43	0.22
11	10	2.35	4.52	0.23
12	10	2.2	4.43	0.22
Σ	—	—	73.48	3.70
Avg.	—	—	4.5925	0.23125
Standard deviation, σ			0.3226	0.01746

[1] Samples marked "A" are aliquots of preceding number after having stood overnight.

TABLE VI. Effect of Lead on the Determination of Copper with Dithizone

Sample	Beckman Spectrophotometer					Fisher Electrophotometer			
	Lead (p.p.m.)	Optical Density	pH	Copper		Reading		Copper	
				(gamma)	(p.p.m.)	Scale A	Blank	(gamma)	(p.p.m.)
10A	10	0.093	2.2	4.29	0.21	39.5	8.6	4.00	0.20
10B	10	0.099	3.1	4.56	0.23	39.9	9.0	4.18	0.21
50A	50	0.113	2.25	5.21	0.26	42.7	11.8	5.40	0.27
50B	50	0.095	2.1	4.38	0.22	40.6	9.7	4.48	0.22
Blank	—	—	—	—	—	30.9	—	—	—

in which x is the deviation from the mean, n is the number of results, and $n - 1$ is the number of degrees of freedom.

The presence of appreciable amounts of lead in the samples gave a precipitate of lead sulfate when the samples were fumed with sulfuric acid. The interference of lead was checked, and it was found that the results were somewhat higher if 50 p.p.m. of lead were present, but the difference in the amounts of copper determined with and without lead added was not significant.

A solution containing 1 mg. of lead per ml. was prepared by dissolving 0.1155 gm. of lead dioxide in a mixture of 5 ml. of hydrochloric acid and 5 ml. of nitric acid. The solution was boiled to remove the oxides of nitrogen and then diluted to 100 ml. with double distilled water. One-ml. and 5-ml. quantities of the above solution were added to 50-ml. samples of sewage on which the copper had previously been determined by the dithizone method. This gave sewage samples containing 10 and 50 p.p.m. of lead. The copper content of these samples was determined by the dithizone method. The results are shown in Table VI.

Experiments also were made to determine the effect of large amounts of mercury; that is, 200 to 1,000 micrograms. A solution containing 1 mg. of mercury per ml. was prepared by dissolving 0.1358 gm. of mercuric chloride in double distilled water and making up to 100 ml. One-ml. and 5-ml. quantities of the solution were added to 100 ml. of sewage as before, and the samples taken through the dithizone procedure. When the dithizone was added it turned yellow. The 10 per cent potassium iodide will tie up as much as 20 micrograms of mercury (1). As these samples contained 200 and 1,000 micrograms of mercury, the green dithizone color returned upon the addition of potassium iodide, but it was not as dark a green, showing that not all of the dithizone was released from the mercuric-dithizone complex. The usual reading for the dithizone solution was around 28.2 on the A scale of the electrophotometer. The reading for one of the sewage-plus-mercury samples was 27.2 instead of about 40.0. Obviously, large amounts of mercury interfere, but amounts up to 20 micrograms were permissible (1).

Samples of industrial wastes were analyzed for copper. Analyses were made on samples which had been acid digested, and also on samples taken directly. Several determinations (not acid digested) on industrial wastes were run by the carbamate method to check the dithizone results. Copper was also determined on a mixture of sewage and industrial waste by both the carbamate and the dithizone methods. (Table VII).

A plating waste listed as sample IW-155, having a fairly high copper content and known to contain iron, cyanide, chromium, and nickel, was

TABLE VII.—Copper in Industrial Waste Samples, in P.P.M., as Determined by Fisher Electrophotometer and Beckman Spectrophotometer

Sample No.	Modified Dithizone Method		Carbamate Method		Electrolytic
	Digested	Undigested	Digested	Undigested	
IW-155	15.20	15.04	—	14.70	15.1
	15.20	14.40	—	14.80	—
	15.45	15.32[1]	—	14.80	—
	15.45	14.92[1]	—	—	—
	15.65	—	—	—	—
IW-62	6.91[1]	6.83[1]	—	6.85	7.2
	6.83[1]	7.02[1]	—	6.60	—
	6.91[1]	6.91	—	6.65	—
	6.91[1]	6.62	—	—	—
	6.68[1]	—	—	—	—
	6.87	—	—	—	—
	6.67	—	—	—	—
	6.97	—	—	—	—
	6.80	—	—	—	—
	6.67	—	—	—	—
Mixture[2]	0.180[3]	—	0.180[3]	—	0.177[3,4]
	0.175[3]	—	0.172[3]	—	—
	0.180[3]	—	—	—	—
	0.171[3]	—	—	—	—

[1] Beckman spectrophotometer.
[2] 10 ml. of IW-155 and 100 ml. of sewage.
[3] In milligrams.
[4] Calculated.

chosen for the first determination. A 2-l. sample of IW-155 was evaporated to approximately 100 ml. After addition of 10 ml. of nitric acid the sample was boiled for about 5 min. The sample was cooled, transferred to a 500-ml. Erlenmeyer flask, and 10 ml. of sulfuric acid was added. This solution was then brought to fumes, was digested for a few minutes, and was cooled. About 100 ml. of distilled water was added, and the sample was filtered through Whatman 41H filter paper. After filtering and washing, 10 ml. of concentrated nitric acid was added and the solution was plated for ½ hr. on a weighed platinum electrode at 6 amperes and 4 volts. Several crystals of urea were added from time to time. The electrode was removed from the machine, rinsed several times with distilled water, once with acetone, and dried and weighed. The amount of copper plated was 0.0302 gm. The copper was stripped from the electrode with nitric acid, the electrode reweighed, and the sample replated for about 15 minutes to test for copper remaining in solution. No more copper plated out. Sample IW-155, therefore, showed a copper content of 15.1 p.p.m.

Five 10-ml. samples of IW-155 were pipetted into Erlenmeyer flasks. Five ml. of concentrated nitric acid and 5 ml. of concentrated sulfuric acid were added and the samples were evaporated to fumes. Twenty ml. of double distilled water was added and the samples brought to fumes again. This was repeated once more. The samples were cooled, transferred to 50-ml. volumetric flasks, made up to volume, and 1 ml. aliquots taken for analysis. A blank of 5 ml. of concentrated nitric acid and 5 ml. of concentrated sulfuric acid was also taken.

To see if the dithizone method could be used for samples which had not been digested, a 10-ml. sample was taken of IW-155. It was diluted to 1,000 ml. with double distilled water and two 25-ml. samples were taken for analysis. Colors were read on both the Beckman spectrophotometer and the Fisher electrophotometer (see Table VII).

Another industrial waste sample was selected for further tests. Qualitative analysis of this sample, IW-62, showed the presence of copper, manganese, nickel, iron, aluminum, and chromium. An electrolytic copper determination showed it to contain 7.2 p.p.m. Analyses were made first without fuming. A 25-ml. sample was taken, transferred to a 1-l. volumetric flask, and diluted to 1,000 ml. with distilled water. Two 25-ml. aliquots were taken for analysis. Readings were again made both with the Beckman spectrophotometer and the Fisher electrophotometer (Table VII).

Analyses were also made by the dithizone method in the regular manner. Five 10-ml. samples were placed in Erlenmeyer flasks, 5 ml. of concentrated nitric and 5 ml. of concentrated sulfuric acid were added, and the samples were taken to fumes three times as before. A blank was also run.

These samples were made up to 50-ml. volume, 2-ml. aliquots were taken for analysis, and readings were again made on both instruments (Table VII).

Two samples of sewage mixed with a plating waste were prepared by adding 10 ml. of IW-155 to each of two 100-ml. samples of raw sewage. Five ml. of concentrated nitric acid and 5 ml. of concentrated sulfuric acid were added to each, and the samples were brought to fumes three times as before. A blank was also taken. These samples were transferred to 50-ml. volumetric flasks, made up to volume with double distilled water, and 1-ml. aliquots taken for analysis. Colors were read on the Fisher electrophotometer (Table VII). From prior analyses it was known that there was 0.154 mg. of copper in 10 ml. of IW-155, and 0.023 mg. in 100 ml. of sewage, or a total of 0.177 mg. in the mixture.

As the dithizone method used considerable carbon tetrachloride it appeared advisable to reclaim the used solvent. The method given by Biddle (4) was used. A preliminary separation of dithizone from solvent was effected by shaking with dilute ammonium hydroxide, removing the aqueous layer, and washing the solvent with commercial sulfuric acid until colorless. The carbon tetrachloride was then treated with calcium hydroxide and distilled twice from an all-pyrex apparatus in the presence of an excess of calcium hydroxide. The effect of diffused light and time on dithizone samples using new and reclaimed carbon tetrachloride showed that the reclaimed material was entirely satisfactory.

Sodium Stearate Method

Seekles, Havinga, and Bijerk (6) suggested a method for concentrating copper and freeing it from other ions by simple filteration through sodium stearate. The procedure seemed so promising that it was investigated. Results were very erratic and good recoveries was certainly not a function of the time of filtering.

Benzidine Sulfate Method

The determination of copper with benzidine sulfate (7) seemed to present a good method with which to supplement the dithizone method, as the only interfering ion was silver and the range of copper which could be determined was from 0.02 to 2.0 mg.

This method did not prove at all satisfactory, as the results given by Mellan (7) were never obtained in this laboratory. The maximum copper concentration gave only the faintest pink color instead of a deep red. The method is limited by the fact that the color must be compared within 5 min.

Carbamate Method

A. General

The sodium diethyldithiocarbamate method, known as the carbamate method, is the one now recommended as standard (8) for the determination of copper in water. Due to many interfering ions, the method has not been very useful for determining copper in sewage or industrial wastes.

The preliminary experiments using this method were performed as outlined in the standard methods (8), but in later work the procedure followed was that given in Sandell (9), as the latter seemed to offer greater ease of manipulation. Sandell used a 20 per cent solution of ammonium citrate to remove interference due to iron, whereas the standard method uses bipyridine and *p*-hydroxyphenylglycine solutions. In Sandell's procedure not more than 5 mg. of iron or 0.5 mg. of manganese should be present in the sample used; that is, in 20 to 30 ml.

B. Reagents

Ammonium citrate, 20 per cent solution—This was prepared by dissolving 17 gm. of hydrated citric acid in about 50 ml. of double distilled water. It was purified by shaking for about 5

min. with dithizone, which was removed by shaking with successive portions of carbon tetrachloride. The solution was then neutralized with ammonium hydroxide to a pale blue (pH approximately 9.0) using thymol blue as the indicator. The solution was then transferred to a 100-ml. volumetric flask and made up to volume.

Sodium diethyldithiocarbamate, 1.0 per cent aqueous—One gm. of sodium diethyldithiocarbamate was dissolved in 100 ml. of redistilled water and the solution transferred to an amber-colored bottle.

Standard copper solution—The same standard copper solution was used as that used for the dithizone method.

C. Procedure

To 100-ml. samples of raw sewage in Erlenmeyer flasks were added 5 ml. of concentrated nitric acid, after which the samples were concentrated to approximately 20 ml. Two ml. of concentrated sulfuric acid was added and the samples evaporated to fumes on the hot plate. The samples then were transferred to separatory funnels, rinsing with 20 ml. of redistilled water. Three drops of thymol blue indicator were added and the solution was neutralized with ammonium hydroxide to a pH of about 9.0 (matching the color of a solution adjusted with the pH meter). Five ml. of the ammonium citrate solution, 1 ml. of carbamate solution, and 10 ml. of redistilled carbon tetrachloride were added to each sample before shaking it for 2 min. The carbon tetrachloride layers were transferred to electrophotometer cells and readings were made on the A scale using filter No. 425 (blue). The results obtained were read from the calibration curve prepared from standards treated in the same way.

D. Discussion

When the standard procedure (8) for the carbamate method was used, an emulsion was formed when carbon tetrachloride was added to the sample in the separatory funnel. This emulsion never was broken completely. The sample was extracted with three 5-ml. portions of carbon tetrachloride, which removed all the color in the emulsion; therefore, the emulsion in the separatory funnel was thought to contain a negligible amount of copper. The carbon tetrachloride portions of the sewage samples were turbid, which was believed due to interfering ions not taken care of in the standard method.

Samples of sewage and industrial wastes were run by both the dithizone and carbamate methods, the latter using the procedure given by Sandell (9). The results obtained with sewage checked those obtained by the dithizone method, but the results on undigested industrial waste samples were somewhat low. This might be due to interference from zinc (see Table VII).

Conclusions

Much more work was done on the determination of copper in sewage and industrial wastes by the dithizone method than by the carbamate method. For this reason the two methods should not be compared.

The dithizone method was chosen because of its increased sensitivity and the fewer interfering ions, and can be recommended as a procedure for determining copper in amounts from 0.04 to 14 p.p.m. in sewage and industrial wastes, when using samples ranging in volume from 25 to 250 ml.

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COMPRESSED YEAST WASTES TREATMENT*

VI. Application of Basic Principles

By Willem Rudolfs and Eugene H. Trubnick

Wastes from the manufacture of compressed yeast have been shown to be composed predominantly of highly putrescible dissolved organic matter, with B.O.D. values of 2,000 to 15,000 p.p.m.; which utilizes oxygen in a manner similar to domestic sewage (1). These wastes can be considered as an example of a great variety of soluble organic wastes, such as distillery, chewing gum, and antibiotic wastes, both as to the nature of the material and its amenability to treatment. It may be expected that the principles involved in the treatment of the yeast wastes would apply to other soluble organic materials.

It has been further shown that although chemical treatment of the material is entirely ineffective and electrodialysis and activated sludge treatment would require long detention periods to produce only partial purification, anaerobic digestion and trickling filter treatment are highly effective methods of handling the waste, producing as much as 94 per cent suspended solids and 85 per cent B.O.D. reduction, respectively, at lower loadings (2). At the Anheuser-Busch yeast plant at Old Bridge, N. J., a representative portion of the total combined wastes from the manufacture of compressed yeast is heated. The plant consists of two holding and equalizing tanks; a two-stage digestion system designed on the principle of a continuous up-flow of the more concentrated liquid wastes through the sludge blanket; a hopper-bottomed circular settling tank for the retention of sludge carried over with the digester effluent; a two-stage high rate trickling filter, 4 ft. deep in each stage and with a 1:1 recirculation ratio, which treats the digester effluent mixed with the dilute portions of the raw waste; and a circular settling tank for clarification of the final effluent (Figure 1).

Under normal operating conditions, with the digesters loaded at the rate of 0.1 lb. B.O.D. per cu. ft. per day and the trickling filters at the rate of 5,000 lb. per acre-foot per day, the plant accomplishes B.O.D. reductions of 80 to 98 per cent, with an average reduction of 90 per cent. Gas production from the digesters averages 7.5 cu. ft. per lb. of volatile matter added, which, at optimum volatile matter loading, is equivalent to between 2.0 and 2.5 cu. ft. of gas per cu. ft. of total digester capacity per day.

Data collected with the large continuous-flow digester units correspond very closely to results obtained in the laboratory with small batch digesters, showing that for the digestion process laboratory studies can be used for control purposes, as well as for predicting large scale operating results, and for investigating contemplated changes in procedure without incurring the possibility of upsetting a normally operating digester. This correlation of laboratory and large scale results could not be attained in the operation of the trickling filters.

The degree of purification attainable was found to vary with environmental conditions; but the most important factor, both with the digesters and the trickling filters, was the daily load put on the units.

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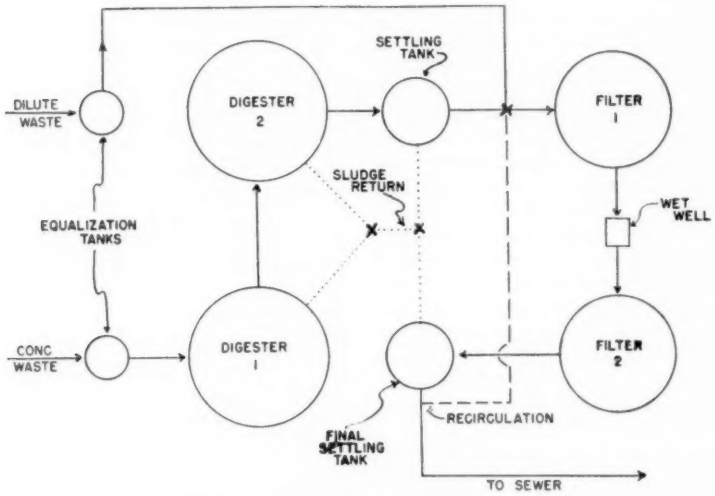

FIGURE 1.—Layout of yeast waste treatment plant.

Factors Affecting Digestion

Acclimitization of Sludge

Because laboratory investigations had indicated that gradual acclimitization of ripe sewage sludge was necessary for optimum results when the sludge was to be used as seed for digesting yeast wastes, operation of the plant was started at low loadings, which were gradually increased over a period of more than 6 months before the maximum load was applied. The seed sludge remained viable for at least 5 years, in spite of frequent and extensive variations in operation. B.O.D. reductions, as well as other indices of purification, were as efficient after 5 years as they were shortly after the start of operations.

Ratio of Seed to Substrate

It has been demonstrated that a minimum volume of 5 per cent sludge equivalent to ⅛ of the effective tank capacity under quiescent conditions is required for proper operation of the digesters at normal loadings. With constant loading, increases in sludge volume beyond this value do not materially improve the performance of the digesters (3). When the sludge volume exceeded ½ of the tank capacity, expansion and excessive carry-over of the sludge occurred.

Contact Between Seed and Substrate

Heukelekian (4) almost twenty years ago noted that agitation of a fresh solids-ripe sludge mixture after the addition of each daily batch of solids resulted in a 28 per cent increase in gas production, indicating increased activity as a result of the thorough mixing afforded by the agitation. In a similar manner, periodic agitation of digesting spent nutrient-sludge mixtures produced in the laboratory a 26 per cent increase in gas production and a 30 per cent increase in B.O.D. reduction (2). Furthermore, agitation of the digestion mixtures resulted in an acceleration of gas production so that peak production occurred within 3 hr. after the introduction of the substrate to the seed sludge, by which

time 50 per cent of the total 24-hr. production of gas was released. The faster release of the gas minimized retention of gas bubbles on the sludge particles and thereby improved the settling qualities of the sludge.

In the treatment plant, distribution was achieved by introducing the liquid waste at the bottom of the digesters and allowing it to flow upward through the sludge to overflow weirs at the top of the tanks. The efficiency of the digesters decreased whenever distribution of the liquid through the sludge was disturbed as a result of short circuiting of the flow. Short circuiting which occurred at high rates of liquid flow was overcome by the installation of horizontal baffle plates. As the sludge became compact with continued usage, increasing from 4 per cent solids at the start of operations to 7 per cent after 5 yr., a tendency toward short circuiting was again noted, because of the greater density of the compacted sludge. This condition is being overcome by the installation of rotating perforated distributors.

Reaction Control

The raw wastes have a pH of 4.0 to 5.5, and are readily buffered by the seed sludge (ammonium carbonate production) to a neutral pH. As might be expected under these conditions, neutralization prior to digestion does not alter the efficiency of the purification processes. However, addition of alkaline materials, such as sodium hydroxide, sodium carbonate, lime, and waste alkali from a nearby paper mill resulted in better separation of the digested liquid from the sludge and afforded increased retention of sludge; therefore, neutralization of the waste prior to digestion has become an integral part of the treatment process.

Loading

By far the most significant factor affecting digester performance was found to be the daily loading applied to the unit (5). Whether the loading was expressed in terms of B.O.D., volatile matter, total solids, or organic nitrogen, either as pounds per cubic

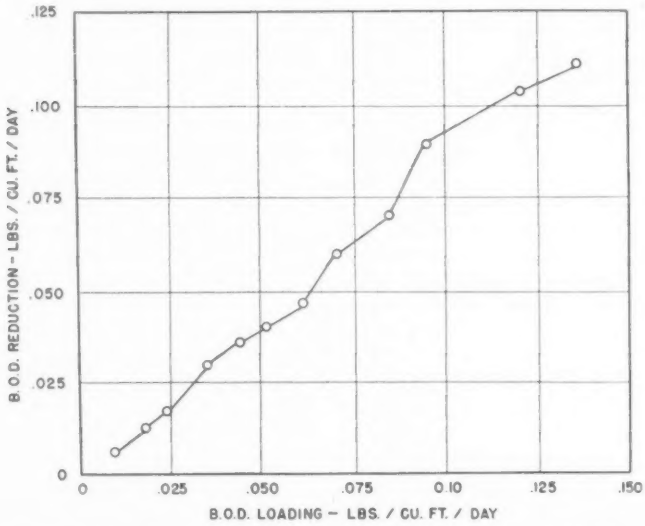

FIGURE 2.—Effect of B.O.D. loading on B.O.D. removal by digestion.

foot per day or as pounds per unit of seed sludge, in all cases a direct relationship was observed between the loading and the performance of the digesters in the removal of polluting substances and in gas production.

As B.O.D. removal is the prime purpose of the digestion of materials such as yeast wastes, a study of B.O.D. reductions in relation to B.O.D. loadings is the best index of the work accomplished in the digester. Maximum daily B.O.D. loadings of 0.136 lb. per cu. ft. of total digester capacity were attained (Figure 2), with indications that still higher loadings could be applied. It was shown (5) that B.O.D. reduction, in terms of actual pounds removed per unit of digester capacity, is directly proportional to the number of pounds added daily, regardless of the detention period (from 1.4 to 3.7 days). In other words, within these limits the concentration of the raw material and the rate of flow through the digesters are not significant factors in the efficiency of the digestion process. The peak efficiency, as measured by percentage B.O.D. reduction rather than by pounds of B.O.D. removed, occurred at a loading of 0.095 lb. per cu. ft. per day in two stages with 95 per cent B.O.D. reduction, and at 0.190 lb. per cu. ft. per day in single-stage digestion with 85 per cent B.O.D. reduction (Figure 3). The apparently low optimum loading of the two-stage digestion, as compared to the one-stage, results from the fact that the two stages were of equal volume, and the partly treated material entering the second stage represents a very low loading. It appears, therefore, that the second-stage tank could be considerably smaller than the first, except for hydraulic consideration. Too small a tank would involve excessively high overflow rates that would reduce effective retention of sludge in the digester. The results indicate that B.O.D. reductions of up to 85 per cent can be accomplished in a single stage, but that a two-stage unit is necessary if higher reductions are required.

Although B.O.D. reduction is the index of choice in determining the efficiency of the digestion process, an analysis requiring 5 days for completion is obviously not suited for day-to-day control purposes. Several other indices, such as solids removal, volatile matter reduction (Figure 4), organic nitrogen removal, and gas production are all functions of loading, and can

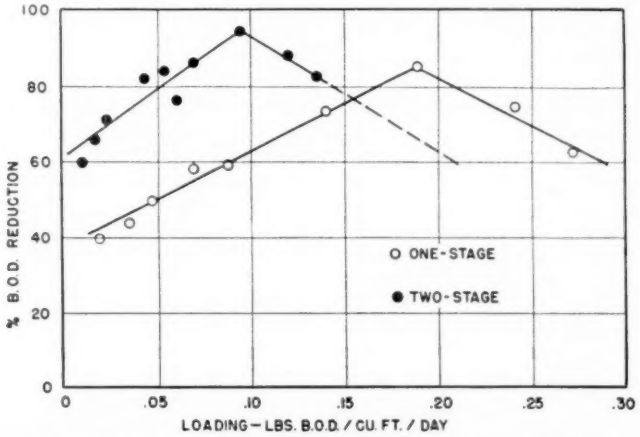

FIGURE 3.—Relation between digester loadings and efficiency.

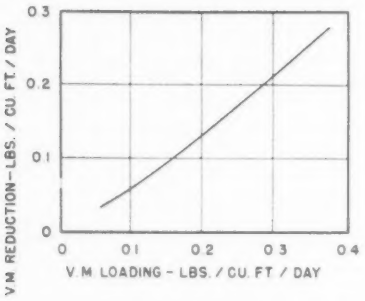

FIGURE 4.—Relation between volatile matter loadings and reduction.

be measured much more rapidly than can the B.O.D. reduction. It is possible, therefore, to use any of these indices for routine control. Maximum loadings of 0.48 lb. total solids, 0.36 lb. volatile matter and 0.02 lb. organic nitrogen per cu. ft. of digester capacity were attained, again with indications that the maximum loading had not been reached.

Considering the daily volatile matter loading in relation to the volatile matter in the sludge, quiescent digestion mixtures could be fed at the rate of 5 per cent volatile matter per day, or at the same rate as usually practiced in sewage sludge digestion. By affording thorough mixing through agitation it was possible to increase the daily loading to 20 to 25 per cent volatile matter

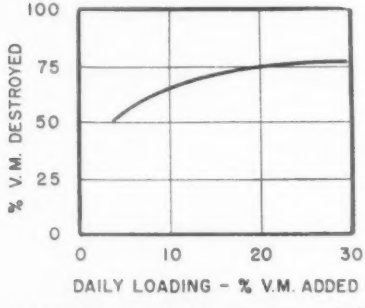

FIGURE 5.—Relation between volatile matter reduction and percentage daily addition.

before retardation of the digestion occurred. Adequate volatile matter removal was achieved with daily loadings of 25 to 30 per cent volatile matter additions (Figure 5). Here again is shown the benefit derived from adequate distribution throughout the sludge blanket of the material to be treated.

Factors Influencing Trickling Filter Treatment

Loading

As was the case with anaerobic digestion, the performance of the trickling filters was found to be a direct function of the applied B.O.D. load

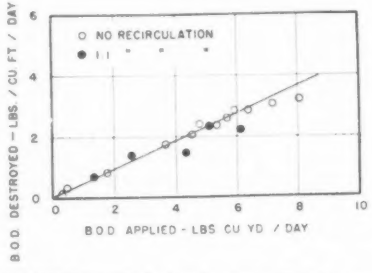

FIGURE 6.—Relation between B.O.D. applied and removed by trickling filters.

(6), with a straight line relationship between pounds of B.O.D. applied and pounds of B.O.D. per cubic yard per day (Figure 6). Recirculation at a 1:1 ratio did not materially improve the performance of the filters; the recirculated effluent served purely as a diluent. Loadings of more than 8 lb. B.O.D. per cu. yd. of stone were applied before any marked decrease in filter efficiency was noted; in the loading range of 0.2 to 8.0 lb. B.O.D. per cu. yd. per day the efficiency of the filters decreased from 58 per cent B.O.D. reduction to 40 per cent (Figure 7). Variation of the rate of surface application between 0.8 and 6.8 m.g.a.d. produced no significant variations in B.O.D. removal.

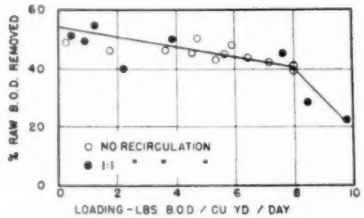

FIGURE 7.—Effect of B.O.D. loading on filter efficiency.

B.O.D. Concentration

At approximately constant loading, dilution of the trickling filter influent resulted in somewhat higher filter efficiency. When the material applied to the filter had a B.O.D. of 1,400 p.p.m. the filter efficiency was 40 per cent, but when the influent was diluted to 200 p.p.m. the efficiency was increased to almost 65 per cent (Figure 8). A considerable amount of cooling water is discharged from the manufacturing process. This water has a temperature of 80° F. and contains a considerable amount of dissolved oxygen. Because the filters can handle dilute wastes more efficiently than the concentrated material, and variations in the rate of surface application do not affect filter performance at a given loading, the cooling waters are included in the filter influent as a part of the treatment process.

Reaction Control

Optimum B.O.D. removal occurred when the pH value of the filter influent

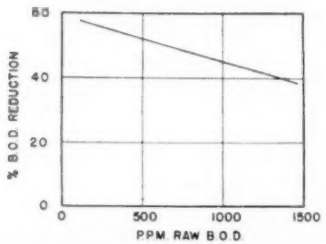

FIGURE 8.—Effect of dilution on filter efficiency.

was 7.0. The filter efficiency deteriorated at lower pH values. Below pH 6.0 the surface of the rock rapidly became coated with a heavy growth of wild yeast, which clogged the filters. Clogging and lowered efficiency could readily be overcome by neutralization of the influent to pH 7.0 with any of several alkaline materials, such as sodium hydroxide, sodium carbonate, or alkaline paper mill waste.

Discussion

The relationship between digester loading and digester efficiency (Figure 3) may be used as a basis for acquiring any desired degree of B.O.D. reduction by varying the loading; in other words, digester capacity and detention time can be determined on the basis of B.O.D. reduction requirements. In practical application this means that the size of a digester and the necessary detention time could be determined by the percentage reduction required. For example, if 100,000 gal. per day of a waste having 5,000 p.p.m. B.O.D. are to be treated by digestion, and a 95 per cent B.O.D. reduction is required, a two-stage digester loaded at a rate of 0.095 lb. per cu. ft. per day would be necessary. At this loading the waste in question could be treated in digesters of 44,000 cu. ft. total capacity, or in a detention period of 79 hr. With the close correlation of laboratory results and full scale operating data previously noted, it appears possible, in planning treatment of a soluble organic waste, to predetermine digester capacities on the basis of information gathered in laboratory studies.

Rankin (7), in a discussion of sewage sludge digestion, has pointed out the close relationship between detention time and digester performance, as measured by volatile matter destruction, and has proposed that detention time be used as a yardstick for evaluating digester performance. It has been shown that digester performance

in the treatment of soluble organic wastes such as yeast wastes is a function of detention time only insofar as the detention time is a reflection of loading, and that a given load will result in a constant efficiency value regardless of whether it is applied as a stronger material for a longer detention period or a more dilute material for a correspondingly shorter period. For this reason, therefore, it appears that an even more universally applicable yardstick than detention time for determining digester performance would be the daily or monthly applied load, either in terms of B.O.D. applied, as with yeast wastes where B.O.D. reduction is the goal of the digestion process, or in terms of volatile matter applied, as in the case of sewage sludge.

Rankin (7) makes the interesting observation that there is no significant difference in the relation of detention and volatile matter reduction between sludges from different processes, whether primary sedimentation, trickling filter, or activated sludge, and goes on to state that the digestible particles or sludge should be hydrolyzed and assimilated by the bacteria at the same rate regardless of the origin of the particle. This universality of results may be expanded on even further. It has been shown above that under quiescent conditions and temperatures used the soluble yeast wastes could be digested at volatile matter loadings up to 5 per cent of the volatile matter content of the seed, or at just about the usual rate of application of sewage sludge. Penicillin wastes and chewing gum wastes (8) have been treated at approximately the same rate of application. Thus, it may be expected that the digestible portion of many wastes, domestic sewage or industrial waste, will be acted upon by the organisms of the seed at the same rate, regardless of the nature or source of the waste. Wastes low in nitrogen or phosphorus may need addition of these chemicals to produce a maximum degree of digestion.

The similarity between results obtained with yeast wastes and with sewage is further demonstrated by examination of the trickling filter data. Just as a straight line relationship between B.O.D. loadings and removals was observed with yeast waste applied at rates of 0.25 to 8.0 lb. per cu. yd. per day, Moore, Smith, and Ruchhoft (9) found that in treating settled sewage on a shallow recirculating filter at Elizabethtown, Ky., there was no evidence of a break in the straight line relationship between the B.O.D. loadings and removals at applications of 1.36 to 6.48 lb. per cu. yd. Both in the Elizabethtown sewage plant and in the yeast waste treatment plant, recirculation of the filter effluent had little, if any, effect on the relationship of B.O.D. removed to load applied.

Further comparison of filter performance with yeast wastes and with sewage indicates a slight but definite decrease in efficiency with increased loadings, which has also been pointed out in a study of sewage treatment at military installations (10) as well as in the Elizabethtown report (9). Similar results have been reported with filter treatment of strawboard wastes (11).

This similarity of results with sewage and with various industrial wastes suggests that a given treatment operation is able to perform a definite amount of work, and that the maximum possibilities of the process are the same regardless of the material being treated. It appears that the principles of sewage treatment are much more applicable to the organic industrial waste treatment problems than has commonly been believed. The often-heard statement that each industrial waste requires a separate approach may be true as far as handling and amenability to treatment are concerned, but the basic principles of sewage treatment seem to apply when a

particular treatment process is concerned, regardless of the origin of the waste being treated.

The findings that maintenance of intimate contact between the seed sludge and the substrate increased digester performance by 26 to 30 per cent and permitted loadings 4 to 5 times greater than was possible under quiescent conditions, corroborate the earlier findings and suggest that development of proper methods of mixing fresh solids with seed sludge in the digestion of sewage sludge may lead to materially increased loadings or reductions in digested capacity requirements. In fact, Fontenelli (12) has recently been able to increase the capacity of the digesters at the Rahway Valley treatment plant by 40 per cent with a corresponding decrease in detention time by maintaining good distribution of the fresh solids throughout the seed sludge.

Buswell (13) reports that continuously operated digesters treating yeast wastes require reseeding every two years, and attributes this fact to a gradual deterioration, or a decrease in viability of the sludge. In view of the experimental evidence of the continued viability of sludge after 5 years, and of the requirement of a minimum amount of sludge for optimum performance, it appears that the need for periodic reseeding may have been due to losses of sludge rather than to any decrease in its biological activity. It is a well established fact that sufficient seed is a prime requisite for proper digestion of sewage sludge and the principle holds true for digestion of other materials as well. It has also been shown that the presence of excessive quantities of seed sludge is detrimental, because it induces sludge losses, which consequently upset digestion processes.

Summary and Conclusions

Combined yeast wastes, consisting essentially of dissolved organic matter, have been treated by a combination of anaerobic digestion and high rate trickling filters, with B.O.D. reductions of 80 to 98 per cent. Optimum purification by digestion depends on proper acclimitization of seed sludge, intimate contact between seed and substrate, maintenance of sufficient quantities of sludge without building up excess quantities, and loading at optimum rates of application. Filter performance is a function of loading, influent concentration, and pH. Results obtained, both with digestion and with the filters, are comparable to what is usually achieved in sewage treatment under similar conditions. Attention is drawn to the fact that the principles of sewage treatment apply to organic industrial wastes.

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WATER CONTAMINATION BY ARSENIC WASTES

Contamination of surface and ground waters in Venezuela by waste arsenic compounds from cattle dipping operations has reached toxic concentrations necessitating drastic control measures and treatment of the contaminated water for human and animal consumption.

For some 15 years Venezuelan cattlemen have used arsenic compounds as dips for control of ticks and other disease spreading insects. When the solution becomes weak or the need for it has passed, it is poured out on the ground. Disposal by this method would not be too bad in a small isolated area; the practice, however, is wide spread.

Low ground-water levels and sparse rainfall during much of the year prevent a slow orderly leaching process that could eventually carry the arsenic compounds to the ocean or allow them to combine with ground materials. Advent of the rainy reason washes the poisonous residues down into the agricultural catchment basins, where it is again redistributed in water for irrigation and cattle. Because of the cumulative effect, the arsenic content of the water has gradually built up to very toxic concentrations.

In an effort to alleviate the condition the Water Laboratory of the National Institute of Sanitary Works (Venezuela), as a result of an inquiry among those who may have had some contact with the same type of problem, has formulated a program and procedures designed to give the desired results. The first step requires that all arsenic dips be replaced with other insecticides proven to be equally as effective as arsenic dip. The second phase is water treatment employing prechlorination, lime adjustment of pH, and coagulation with chlorinated copperas. The third part of the program calls for periodic analysis of public and agricultural water supplies for arsenic content.

THE USE OF STEEL PICKLING LIQUORS FOR SEWAGE SLUDGE CONDITIONING *

By Michael A. Groen

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Municipal sewage treatment plants are public utilities in the same category as power and light plants, water treatment plants, gas plants, or telephone systems, and have had to cope with the universally rising operational costs. However, privately owned utilities may present their cases to the state authorities and usually are granted the right to charge higher rates in order to insure them a guaranteed margin of profit, whereas administrators of municipal sewage treatment plants financed by taxation must consider the citizen taxpayers, who are likewise owners of this particular utility, before requesting additional appropriations.

Dearborn, Mich., was no different from numerous other municipalities that do not assess their communities for sewer rental or sewage treatment charges. However, Dearborn's sewage treatment division felt this increasing cost spiral more than others because the chemical-mechanical process was used instead of the various biological processes, and also because Dearborn pioneered in vacuum filtration and incineration of raw sewage sludge.

The annual budget for chemicals in the form of ferric chloride and lime was a major item, even from the very beginning. In the past few years, however, when the cost of ferric chloride has more than doubled, it was felt that research work would be justified if a suitable substitute for the costly ferric chloride could be found.

With this purpose in mind, plus the added possibility of eliminating one industrial waste as a contributing factor to the serious problem of stream pollution, it was decided to conduct a series of experiments in a truly scientific manner.

Some experimental work in the use of steel pickling liquor wastes for sewage treatment and sludge conditioning was conducted at Dearborn's Greenfield sewage treatment plant as early as 1933. At that time, after preliminary laboratory studies, a plant scale test was run from August 1 to September 15, 1933. The pickling liquor was received from the Ford Motor Company in carboys, however, and the quantities were too small to run continuously. Thus a 20-day test run required a 6-week period. Tests were made comparing the results of using the raw pickle liquor, ferric chloride, and "Calcoag," an anhydrous ferric sulfate. As the data on the work done at that time is incomplete and somewhat fragmentary, it proved to be of little value during the tests made in 1948 and 1949. Therefore, only a few of the operating results are cited.

During the 1933 tests one flocculator and clarifier was used for sewage treated with pickle liquor and another flocculator and clarifier was used for sewage treated with Calcoag. The results are shown in Table I. It should be pointed out that at the time raw sludge was pumped from Dearborn's Miller road plant and added to the Greenfield plant raw sewage, which accounts for the high suspended solids and B.O.D. in the raw sewage samples. On certain dates no sludge was pumped over from the Miller road plant. The pickle liquor used during those trials was quite variable and often had a

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TABLE I.—Comparison of 1933 Results from Treatment of Sewage in Separate Clarifiers with Calcoag and with Pickling Liquor

Date (1933)	Sewage Treated (m.g.)		Suspended Solids (p.p.m.)					B. O. D. (p.p.m.)					Chemicals Used (lb.)				Iron Ratio[3]	D. O. in Effl. (p.p.m.)	
													CaO		Fe				
	Cal.[1]	P.L.[2]	Raw Sewage	Effl. Cal.[1]	% Red.	Effl. P.L.[2]	% Red.	Raw Sewage	Effl. Cal.[1]	% Red.	Effl. P.L.[2]	% Red.	Cal.[1]	P.L.[2]	Cal.[1]	P.L.[2]		Cal.[1]	P.L.[2]
Aug. 1	1.06	1.06	708	28	96	52	93	305	41	87	44	86	243	243	320	320	1.00		
2	1.23	1.23	920	46	95	42	95	301	29	90	30	90	350	350	240	166	1.44		
5[4]	0.84	0.84	1,310	16	99	56	96	180	25	86	26	86	80	80	365	210	1.74		
8	0.76	0.76	1,140	51	96	57	95	342	48	86	44	87	340	340	290	120	2.42		
9	0.86	0.86	1,552	23	99	77	95	444	27	94	63	86	190	190	280	155	1.80		
10	0.78	0.78	1,261	17	99	42	97	401	44	89	34	92	150	150	280	195	1.44		
17	0.87	0.87	1,698	44	97	42	98	716	55	92	44	94	450	450	485	90	5.38		
18	0.83	0.83	1,254	53	96	45	96	500	46	91	34	93	405	405	305	174	1.75	3.3	2.1
19[4]	0.72	0.72	268	29	89	35	87	65	33	50	25	61	144	144	160	75	2.14	4.4	2.1
20[4]	0.65	0.65	200	21	89	23	89	88	21	76	31	65	110	110	120	67	1.79	5.8	3.2
21	0.81	0.81	658	46	93	32	95	296	37	88	56	81	513	513	345	90	3.84	4.9	2.9
22	0.81	0.81	865	49	94	37	96	297	32	89	31	90	468	468	310	240	1.29	3.9	2.2
23	0.81	0.81	1,171	32	97	25	98	366	39	89	31	92	432	432	320	270	1.19	4.0	1.3
29	0.79	0.79	838	34	96	44	95	298	47	89	35	88	296	392	240	280	0.86		
30	0.86	0.86	1,325	38	97	34	97	445	38	91	36	92	340	460	280	180	1.55	2.0	1.5
31	0.65	0.65	438	32	93	33	92	175	36	79	32	82	110	150	105	68	1.55	2.1	1.3
Sept. 1	0.78	0.78	1,687	31	98	23	99	609	26	96	86	86	423	562	360	315	1.14	1.6	1.0
6	0.82	0.82	1,247	21	98	23	98	563	35	94	44	92	945	945	590	61			
13	0.75	0.75	1,151	23	98	30	97	474	15	97	17	96	550	1,100	790	203	3.92		
15	0.75	0.75	2,685	30	99	29	99	832	43	95	45	95	981	981	1,085	497	2.18	3.1	1.7
Total	16.43	16.43	22,376	630		781		7,697	717		788		7,520	8,465	7,270	3,776	38.42	35.1	19.3
Max.	1.23	1.23	2,685	53	99	77	99	832	55	97	86	96	981	1,100	1,085	497	5.38	5.8	3.2
Min.	0.65	0.65	200	16	89	23	87	65	15	50	17	61	80	80	105	61	.86	1.6	1.0
Ave.	0.82	0.82	118	31	97	39	97	385	35	91	39	90	376	423	363	188	1.92	3.9	2.1

[1] Calcoag (anhydrous ferric sulphate).
[2] Pickling liquor.
[3] 1.74 parts Calcoag to 1 part $FeSO_4$.
[4] Sewage only; no sludge from Miller Road plant.

high acid content. Table II shows the variations in the different shipments. It should be noted that the specific gravity varied from 1.184 to 1.292, the free acid varied from 2.13 to 4.81 per cent, and the $FeSO_4$ varied from 6.3 to 21.5 per cent. The chemical feeding equipment, made of "Duriron," stood up well for a year using ferric chloride, but corroded very badly in one month with pickle liquor.

Very little work was done in 1933 on sludge conditioning with pickle liquor prior to vacuum filtering. This was chiefly due to the discouraging results obtained in the initial trials. It should also be pointed out that at this time vacuum filtration of sewage sludge was still in its infancy and the conditioning of sludge was done in batches in sumps, where 2,700 gal. of sludge were conditioned at one time by adding one carboy of ferric chloride and then mixing by air, instead of the continuous conditioning method, with mechanical paddle agitators, now used. It can readily be seen why the painted walls throughout the plant turned black when the sludge was mixed with a high acid content pickle liquor, particularly when using air as a means of mixing.

TABLE II.—Composition of Pickle Liquor Used in 1933 Tests

Date (1933)	Spec. Gravity.	Free Acid (%)	$FeSO_4$ (%)	Amount (carboys)
July 31	1.292	2.13	21.5	50
Aug. 7	1.198	4.36	9.0	50
Aug. 16, 17, and 18	1.221	3.90	12.2	50
Aug. 21	1.252	4.43	14.7	29
Aug. 28	1.281	4.26	19.3	29
Aug. 28	1.252	4.28	15.0	6
Sept. 1	1.184	4.68	6.3	33
Sept. 12	1.228	3.82	13.6	33
Sept. 14	1.212	4.81	9.0	23
Sept. 22	1.212	4.59	9.5	29

According to the 1933 records only two plant scale trials were conducted using pickle liquor for sludge conditioning. The first trial, using 75 lb. of ferrous sulfate to one 2,700-gal. sump of liquid sludge, produced very indifferent results on the vacuum filters. The second trial, on two sumps of sludge using a dosage of 94 and 144 lb. of ferrous sulfate, respectively, filtered very well, producing a cake that averaged 45 per cent solids. Filtering rates as high as 9 lb. of dry solids per square foot of filter area per hour, were obtained.

1933 Observations and Conclusions

The item of cost was seriously considered. It was found that 21 man-hours were required to return 50 empty carboys to the Ford Motor Company and replace them filled at the treatment plant. Labor charges at 50¢ per hr. came to $10.50, to which must be added $4.00 for the use of a truck, making a total of $14.50.

Fifty carboys of 10 per cent ferrous sulfate would contain about 500 lb. Therefore, the cost to Dearborn would be approximately $3.00 per 100 lb. Also, the time required to handle the $FeSO_4$ in the plant was about 4 times as great as for a 40 per cent solution of $FeCl_3$.

The following are the conclusions contained in a report made September 30, 1933, to the Dearborn commissioner of public works:

> "From these observations and a study of the analyses made on actual plant scale operation as well as results obtained in the laboratory under more optimum and better controlled conditions, the use of ferrous sulfate in the form of pickling liquor should be altogether practical here, and entirely suitable to use in sewage treatment as a coagulant. As a conditioner of sludge it is doubtful if it would work. It should at least be experimented with further before a decision is made."

Revival of Interest in 1947

Although the possibility of using steel pickling liquor waste was discussed and further experimental work was contemplated at various times

since the initial trials in 1933, it was not until the spring of 1947, that the subject came up for discussion again. At that time J. E. Cooper, of the Ford Motor Company, proposed to Detroit officials a planned study of the use of pickling liquor on a truly scientific basis.

Approximately 200 Buchner funnel conditioning tests were run at the Detroit Plant under the joint direction of Mr. Cooper and F. H. Burley. C. A. Habermehl, of Detroit, assisted by a chemist from the Ford Motor Company, conducted the experimental work. The purpose of the laboratory study was to determine the following:

1. Will a slurry of ferrous hydroxide condition sludge?
2. Will a slurry of ferric hydroxide condition sludge?
3. Will raw waste steel pickling liquor, just as it comes from the pickling process, function as a conditioning agent?
4. What is the optimum dose? And the quantity of lime required, if any, with its use?
5. Will either of the above agents work as well as ferric chloride?
6. What effects will it have on plant equipment?
7. Evaluation of the above, plus any other pertinent data.

After the extensive experimental work at Detroit, numerous additional tests were conducted at Dearborn under the joint direction of Mr. Cooper and the writer, aided by V. Duranceau, a chemist from the Ford Motor Company's Water and Waste Laboratory. A search of the literature did not reveal any work which had ever been carried on using pickling liquor and lime in the form of acetylene waste for the treatment of sewage or for sludge conditioning.

In 1934, Mohlman and Edwards (1) reported that chlorinated copperas is inferior to ferric chloride as a coagulant. Their work has probably exerted a greater tendency against further coagulation tests using ferrous or ferric sulphate, more so than the unfavorable early experiences at Dearborn in 1933.

A summary of the laboratory work conducted proved the following:

1. A slurry of ferric hydroxide will not condition sludge.
2. A slurry of ferrous hydroxide will not condition sludge, except that when first added to the sludge an immediate effect is noticed, but shortly disappears.
3. Raw steel pickling liquor and lime will condition sludge.
4. The optimum doses are 4 per cent raw pickle liquor and 6 per cent lime.
5. The raw pickling liquor and lime condition sludge as well as ferric chloride and lime.

1947 Plant Scale Test

For the first plant-scale test at Dearborn, in November, 1947, the waste steel pickling liquor came from the Ford Motor Company and showed 4.55 per cent iron and 5.0 per cent H_2SO_4. Laboratory tests showed 9.2 per cent solids in the sludge, or, assuming 65 per cent volatile sludge solids, 0.79 lb. of solids per gallon of sludge.

Using the above solids value, a laboratory conditioning test was carried out using 200 ml. of the sludge and adding 10 per cent lime (CaO) and 6 per cent $FeCl_3$. A vacuum break was obtained at 0.75 min. A similar conditioning test was run using 200 ml. of sludge and adding 10 per cent lime and pickling liquor equivalent to 6 per cent ferric chloride based on iron content. A vacuum break was obtained at 1.05 min. and good conditioning was noted.

Based on this rate of dosage, the plant scale test was started at 11:30 A.M., November 19, 1947, using Miller Road plant wet sludge, with a solids content of 9.2 per cent and 65 per cent volatile. The lime slurry was fed into the 4 × 6-ft. conditioning tank at the

point of incoming sludge flow. The pickling liquor was fed approximately 18 in. behind the lime slurry, so that the lime would be distributed throughout the sludge before the pickling liquor was added.

Previous laboratory conditioning tests had indicated better results when the pickling liquor was added to a sludge in which the high alkalinity had been completely distributed. It has been found that this practice was also advocated by others who had experimented with chemical coagulants for both sewage and sludge; particularly, Mohlman and Edwards (1) and Babbitt (2).

The vacuum filter used was an Eimco 8 × 12-ft. sludge filter having a filter area of 300 sq. ft. It was timed at 2.68 min. per revolution. The chemical feed was actuated by the rate of sludge feed from a bucket elevator. During this test numerous changes were made as to the rates of sludge feed to the vacuum filter, chemical dosage, filter speed, paddle speed in the conditioning tank, etc. Since a limited amount of pickling liquor was available for the test, it was completed in 7 hr. It served, however, as an indication that laboratory tests could be duplicated in the plant to a certain extent, and that additional test runs of longer duration were warranted.

Data for the 7-hr. test include the following:

Sludge treated during 7-hr. test (gal.)	9,050.5
Solids in sludge from composite analysis (%)	7.5
Sludge solids (dry basis) (lb.)	5,660
Sludge solids (lb. per gal.)	0.626
CaO used during test (lb.)	540
Pickling liquor used during test (gal.)	315
Pickling liquor analysis	
Specific Gravity	1.18
$FeSO_4$ (as Fe) (%)	4.55
Acid (as H_2SO_4) (%)	5.0
Chemical feeds per pound of sludge solids	
Lime (as CaO) (%)	9.5
$FeSO_4$ (as Fe) (%)	2.5

The chemical feeds are average values embracing the entire test in relation to materials handled and do not necessarily represent the most efficient additions. The filter yield, taken from a composite of 4 separate hourly samples and calculated from the weight of 1-sq. ft. samples of wet filter cake, was 3.12 tons of filter cake per hour, containing 30.5 per cent solids, or 6.36 lbs. of dry solids per square foot of filter area per hour.

Observations

All during the test the liquid sludge appeared to be well conditioned, having a coarse granular appearance, resembling curds, with visible streaks of water separating from the solids. The filter cake peeled off the filter very readily, averaging ¼ to 5/16 in. in thickness. At times the cake seemed to be coming off somewhat wetter than usual; however, this may have been due to interruptions of feed or to too rapid changes of chemical dosage.

In conclusion, it can be said that the sludge filtered in a manner very comparable to a filter cake using ferric chloride. After the test run the filter was washed with water only, instead of with the usual water wash, dilute acid wash, and another water spray wash.

The filter appeared to wash satisfactorily and close inspection of the filter cloth showed the openings and texture to be normal and no calcium deposits or other coating was noted at that time. The winding wire was also inspected and was noted to be unchanged. The following day the same filter was placed in operation and no acid bath was required to give satisfactory results.

1948 Plant Scale Test

The results of the 7-hr. plant scale test of November 19, 1947, proved gratifying to the extent that plans were made for a 30- to 60-day continuous test run. This, however, would require

a means of transporting large quantities of the pickling liquor. Procurement of an acid-proof tank truck of sufficient size for this purpose was indeed a problem. A railroad tank car was considered, but besides being not practical from an economic standpoint, was not available. Finally, a trucking concern having a 2,000-gal. tank truck was engaged by the Ford Motor Company to deliver the acid to Dearborn's plant in March, 1948. After delivering several loads the tank developed numerous leaks and had to be replaced. This time the tank was made acid proof, which required another 6 weeks. It was April 30 before a dependable schedule of delivery could be established.

On May 1, 1948, an extended plant scale test was begun. The test ran for 10 days before it was interrupted by inundation of power lines in the pipe galleries, causing suspension of operations for 6 days, May 11 to 16 inclusive. Also, due to difficulties in receiving sufficient quantities of pickling liquor, the test was again interrupted from May 21 to May 26, and from May 31 to June 7. When the test was completed on June 14 it had totaled 25 days. The data, given in Table III, are summarized as follows:

Total sludge filtered (gal.)	796,252
Total wet filter cake produced (tons)	1,285.5
Total dry solids produced (tons)	475.06
Average solids in filter cake (%)	37.0
Average combustibles in filter cake (%)	48.8
Total filter time (hr.)	824.3
Filter yield (lb. dry solids/sq. ft./hr.)	3.84
Pickling liquor used (as Fe) (lb.)	11,580
Lime used (as CaO) (lb.)	79,950

TABLE III.—Data for 1948 Plant Scale Test Using Pickling Liquor and Lime for Sludge Conditioning

Date, 1948	Sludge to Filters (gal.)	Sludge Cake (tons)	Sludge Dry Solids (tons)	Analysis		Chemicals		Filter Hours
				Solids (%)	Volatile (%)	Pickle Liquor, as Fe (lb.)	Lime, as CaO (lb.)	
May 1	32,446	45.8	17.04	37.2	49.5	260	2,200	24:00
2	31,290	45.1	16.78	37.2	49.5	233	2,100	40:00
3	33,600	45.7	17.78	38.9	50.1	217	2,560	41:15
4	32,394	47.7	18.56	38.9	50.1	233	2,250	48:00
5	49,508	53.3	18.97	35.6	50.9	389	3,400	46:30
6	50,663	57.5	21.62	37.6	48.8	345	3,500	46:45
7	48,553	51.0	23.05	45.2	50.1	649	3,900	47:30
8	35,501	50.4	18.80	37.3	47.2	505	3,550	45:45
9	27,846	48.5	18.09	37.3	47.2	407	3,100	40:45
10	17,000	51.9	18.37	35.4	48.1	370	2,600	22:00
17	30,493	53.2	19.79	37.2	49.5	583	3,750	38:00
18	39,323	65.0	25.29	38.9	50.1	656	4,250	42:45
19	49,323	62.3	22.18	35.6	50.9	727	3,750	45:45
20	42,735	66.4	24.97	37.6	48.8	694	4,010	46:30
27	22,365	49.3	17.90	36.3	55.8	320	2,250	24:00
28	33,496	57.2	20.76	36.3	55.8	654	3,250	25:00
29	25,306	50.3	18.76	37.3	43.3	486	2,460	23:30
30	14,406	25.3	9.23	36.5	44.9	288	1,410	10:30
June 8	26,807	44.6	15.97	35.8	47.2	628	3,340	23:00
9	28,981	58.4	18.98	32.5	43.0	554	4,500	24:00
10	26,145	58.2	20.08	34.5	47.6	554	3,950	24:15
11	23,940	48.6	17.59	36.2	45.9	470	3,920	20:50
12	24,570	50.4	18.19	36.1	49.0	442	3,580	23:45
13	24,938	50.3	18.15	36.1	49.0	468	2,980	24:00
14	24,623	49.1	18.16	37.0	47.2	448	3,390	26:00

Iron per pound of dry solids filtered (lb.)	0.0122
CaO per pound of dry solids filtered (lb.)	0.0842

The results obtained during the 1948 trials did not appear to be exceptional in regards to tonnage, low chemical dosages, or filter yield. The prime purpose of this trial was to prove that a filter cake could be produced sufficiently low in moisture content to burn in the incinerators economically. From the tabulation of daily data (Table III) it will be noted that the filter hours averaged 33 per day, from a minimum of 10.5 to a maximum of 48. It will also be noted that there was a wide daily variation in chemical dosage. This was purposely carried on so as to observe operating conditions from one extreme to the other, with effects on filters and other equipment noted.

1949 Tests

The test run in May and June, 1948, confirmed the earlier belief that the use of pickling liquor and acetylene waste as lime was entirely practical for sludge conditioning prior to vacuum filtration, and offered a means of effecting considerable economies. Although it was felt reasonably sure that this process was the answer to the quest for a cheaper substitute for the costly ferric chloride, it was likewise felt that additional work should be done before definitely committing the plant by making the necessary changes in the chemical handling equipment on a permanent basis. To receive sufficiently large quantities of the pickling liquor waste to permit continued full plant scale operation would have entailed a hardship on the Ford Motor Company, as the method of loading there had been temporary thus far.

After several meetings between Ford Motor Company officials, representatives of Detroit's sewage treatment plant, and Dearborn officials, the Ford Motor Company decided to build large holding tanks at its Rouge River plant, together with loading facilities, etc. This, incidentally, involved quite a project and considerable expense. The approximate time for commencement of regular deliveries of the pickling liquor was very indefinite, with estimates ranging from 6 months to a year hence.

Second Source of Pickling Liquor

In the meantime, other sources of the pickling liquor were explored. It was found that there was an unlimited supply of the pickling liquor waste readily available at numerous steel mills in the immediate vicinity. In fact, for years it has been a major problem for the steel mills to dispose of this waste.

In December, 1948, the Murray Corporation of America was found to be anxious to dispose of approximately 10,000 gal. of pickling liquor per week. Because so much enthusiasm was felt about continuing experimental work with the pickling liquor, the writer arranged for delivery of their entire output to the Greenfield sewage treatment plant, thereby solving the Murray Corporation's major industrial waste problem and at the same time affording an opportunity to carry on additional experimental work in this respect.

Numerous Difficulties Encountered

The first shipment of pickling liquor from the Murray Corporation was received on December 18. The initial shipment of 6,000 gal. was received while still hot and was dumped into the 12,500-gal. storage tank on a Saturday. Samples were taken from each 2,000-gal. truckload for analysis. The iron content was well over 9 per cent, and as the liquor cooled the excess ferrous sulfate crystallized out and plugged the pipe lines. Such difficulties had not been anticipated, as they had not occurred with the Ford pickle liquor in recent years. The Murray Corporation likewise did not anticipate this trouble, because when some strong

pickling liquor was dumped into an outdoor storage tank, it also crystallized and steam had to be applied to redissolve the crystals. After that experience the iron concentration was kept below 6 per cent by dilution with water.

After a few trials it was decided to standardize the pickling liquor solution at 0.5 lb. of iron per gallon of solution, so as to avoid crystallization at extremely low temperatures and also to give a value easy to use in calculations. A graph (Figure 1) was plotted whereby a relation of the iron content could be made to the specific gravity. Obviously any marked variation in the H_2SO_4 content will throw the curve out of line. It does, however, serve its purpose whenever a load of pickling liquor is delivered after the laboratory technicians have gone for the day.

The numerous difficulties encountered did not help the morale of the various shift operators, who persisted in predicting a lot of trouble with blinding of filter cloths, and in not being able to get sufficient tonnage of filter cake to dispose of the necessary volume of sludge. At first trouble was encountered, but by trial and error the operators began to find the proper rates to use. By close cooperation, however, remarkable interest was aroused, to the extent that individual experimentation and the keeping of a detailed log of the work carried on resulted in some remarkable accomplishments.

Not only were various rates of feed and different proportions of pickling liquor to lime used, but numerous positions for adding the chemicals also were tried. When both lime and pickling liquor were added in the sludge conditioning tank, it seemed to make no difference which was added first. On several occasions, however, the filter cloth on one of the vacuum filters began to blind excessively at the sludge inlet end. As the opposite end did not blind, it was thought that the sludge was entering the vacuum filter vat before it was thoroughly conditioned, and that by the time it reached the far end of the filter tank it was better mixed because of the longer detention time, and therefore filtered better. Feeding the pickling liquor directly into the sludge sump, before the

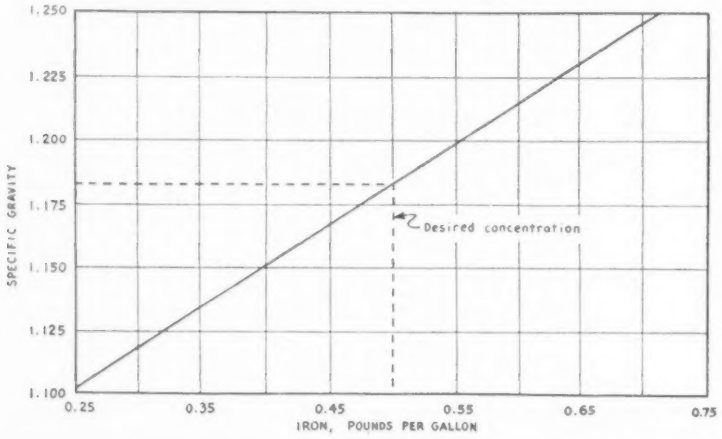

FIGURE 1.—Relation between iron content and specific gravity of steel pickling liquor wastes.

TABLE IV.—Comparison of Sludge Treatment During First Four Months of 1947, 1948, and 1949

Month	Dry Solids (tons)	Filter Cake		Chemicals Used (lb.)				Filter Operating Time (hr.)	Filter Yield (lb. solids/sq. ft./hr.)
		Moisture (%)	Volatile (%)	$FeCl_3$,[1] as Fe	Lime, as CaO	Per Lb. Dry Solids			
						Fe	CaO		
(a) 1947—Using $FeCl_3$									
Jan.	402.51	69.9	56.9	5,660	71,430	0.0070	0.0887	728.50	3.68
Feb.	212.90	70.4	57.4	3,230	38,390	0.0076	0.0902	405.25	3.50
Mar.	166.20	70.4	56.3	2,238	24,120	0.0067	0.0725	293.25	3.78
Apr.	118.43	64.4	57.3	1,979	19,930	0.0084	0.0841	282.00	2.80
Total	900.04	—	—	13,107	153,870	—	—	1,709.00	—
Average	—	68.8	57.0	—	—	0.0074	0.0839	—	3.44
(b) 1948—Using $FeCl_3$									
Jan.	113.83	72.5	58.6	2,345	23,550	0.0103	0.1035	286.00	2.65
Feb.	173.45	70.2	58.8	4,385	41,550	0.0127	0.1198	439.80	2.63
Mar.	253.91	66.9	52.3	2,721	40,780	0.0054	0.0803	435.25	3.89
Apr.	185.60	66.0	49.1	1,793	25,370	0.0049	0.0684	238.00	5.20
Total	726.79	—	—	11,244	131,250	—	—	1,399.05	—
Average	—	68.9	54.7	—	—	0.0083	0.0930	—	3.59
(c) 1949—Using $FeSO_4$ (Waste Pickle Liquor)									
Jan.	256.56	62.3	52.1	9,749	46,700	0.0190	0.0910	453.15	3.77
Feb.	322.92	64.8	50.9	7,459	49,990	0.0116	0.0774	464.00	4.64
Mar.	125.07	67.2	55.2	4,119	22,100	0.0165	0.0884	243.00	3.43
Apr.	461.33	64.0	53.6	10,875	63,050	0.0118	0.0683	708.00	4.34
Total	1,165.88	—	—	32,202	181,840	—	—	1,868.15	—
Average	—	64.6	53.0	—	—	0.0147	0.0813	—	4.05

[1] $FeSO_4$ (waste pickle liquor) in 1949.

bucket elevator brings it up to the sludge conditioning tank cut the cloth blinding to a bare minimum.

Practically all of the early work had been carried on under the theory that the ferrous sulfate should be added to a sewage or sludge having a high alkalinity. This assumption was proved erroneous, at least with the type of sludge found in Dearborn. Another possible reason for the improvement in filtering after adding the pickling liquor in the sludge sump is the fact that when the sludge elevator buckets go down in an inverted position they carry an equivalent amount of air to the bottom of the sludge, thereby oxidizing the ferrous sulfate to ferric sulfate. From Table IV it will be noted that for the month of April, 1949, a total of 461.33 tons of dry solids were filtered using 0.0118 lb. of Fe per pound of dry solids, producing a filter cake of only 64.0 per cent moisture. The percentage of lime was likewise proportionately low. A summary of

the data from the 4-month test in 1949 is as follows:

Period of test	Jan. 1 to Apr. 30, 1949
Total sludge filtered (gal.)	2,439,197
Total wet filter cake produced (tons)	3,356.5
Total dry solids produced (tons)	1,165.88
Average solids in filter cake (%)	35.4
Average combustibles in filter cake (%)	53.6
Total filter time (hr.)	1,868.15
Dry solids (lb. per sq. ft. of filter area per hr.)	4.05
Pickling liquor used as iron (lb.)	32,202
Lime used (as CaO) (lb.)	151,840
Iron per pound of dry solids filtered (lb.)	0.0147
CaO per pound of dry solids filtered (lb.)	0.0813

During the trial period the temperature of the sludge in the conditioning tank varied between 52° and 54° F. The pH of the conditioned sludge averaged 12.8. Total solids in the filtrate in a grab sample during average operating conditions was 5,295 p.p.m. and the suspended solids was 64 p.p.m.

The sludge elevators and chemical feeders were calibrated and the scale was checked by weighing 1-sq. ft. samples every 15 min. and multiplying the average weight by the square feet of filter area and the number of filter revolutions per hour to get the tons per hour produced. This estimated tonnage was within 3 per cent of the scale reading, so was assumed to be correct.

Observations

Although four months of continuous plant scale operation may not be considered long enough to give an accurate picture of possibilities, at least some preliminary conclusions can be drawn. To do this, the first four months of operation of 1947 and 1948, when ferric chloride was used, have been tabulated for comparison with the same four months in 1949 when pickling liquor was used.

The moisture content of the sludge cake was 6.2 per cent lower when using pickling liquor than when using ferric chloride. This difference is small, but it can be concluded that the sludge cake is as dry or drier than when using ferric chloride.

The pounds of dry solids per square foot of filter area per hour was 15.1 per cent greater with pickling liquor than with ferric chloride.

In using pickling liquor, 86.1 per cent more iron was used in comparison with ferric chloride (as iron). However, because the pickling liquor is free any excess use is of little consequence and the operators have not been striving to use a minimum amount for satisfactory filtering results.

For the benefit of the steel industry, it might be interesting to know how much can be safely used instead of how little. Other investigators have stated that the lime requirements would go up with the increase in iron consumption, but that premise has likewise been proved erroneous. Lime consumption was actually 8.1 per cent lower with pickling liquor than when using ferric chloride. One investigator claimed a marked drop in the per cent volatile of the sludge cake based on a short run using pickling liquor. However, the Dearborn results, based on a 4-month period, show only a drop of 5.2 per cent in volatile content. From the incineration economy standpoint the decrease is insignificant, because it is more than offset by the 6.2 per cent reduction in moisture content of the filter cake.

Materials and Equipment

The lime used is the residue left over from the manufacture of acetylene. As received it averages 50 per cent moisture and 33 per cent available material measured as CaO. For use it is made up in batches of 1,200 lb. of lime added to sufficient water to make up 400 gal. of solution. Thus, the solution contains 3 lb. of sludge lime, or 1 lb. of CaO, per gallon. This concentration is maintained so as to make a convenient

figure to use for feeder regulations and recording.

The lime is secured locally and hauled to the plant in city owned trucks. The price of the lime is 25¢ per ton at the lime pit. Adding to this the labor costs and charges for a truck, the final cost to the city amounts to $8.50 per ton of CaO.

The pickling liquor, as previously explained, is an acid waste from the steel pickling process. It is delivered to the plant in 2,000-gal. lots, in a tank truck having an acid-proof lining, at no cost to the city. It is stored at the plant in 12,500-gal. rubber-lined storage tanks, where it is diluted to a concentration of 0.5 lb. of iron per gallon of solution.

For feeding purposes, the lime and pickling liquor solutions are transferred to smaller feeder tanks, from which the lime is fed into the sludge conditioning tanks by a calibrated bucket elevator and the acid by a calibrated constant-level feeder. Both chemical feeders have a range of feed from 0 to 100. Operation of these units is practically automatic, as the speed of the sludge bucket elevators, which control the quantity of liquid sludge applied to the vacuum filters, is controlled by a variable speed mechanism and the chemical feeders are directly driven from the sludge elevators. Therefore, once the chemical dosage is determined and set, they will continue to feed in that ratio regardless of the quantities of sludge being handled.

Each sludge bucket elevator has a metered capacity of 3,150 gal. of liquid sludge per hour. The sludge conditioning tanks have a holding capacity of 190 gal. each, the detention period therein ranging from 4 to 10 min. Each tank is equipped with 4 mixing paddles having a speed of 7 to 11 r.p.m.

The vacuum filters are 8 ft. by 12 ft. in size, with an effective filter area of 300 sq. ft. The amount of sludge maintained in the filter tub for optimum operation is about 275 gal.

The filtering cloths are made up of headlining material, similar to 8-oz. duck. Present cost is $19.50 each. While using ferric chloride the average life of a filter cloth was 460 hr. However, with pickling liquor filter cloth life has been consistently more than 500 hr., with a maximum of 600 hr. on several occasions, and an average of 540 operating hours.

Conclusions

In conclusion, it is felt that steel pickling liquor waste is a very satisfactory substitute for ferric chloride. Early apprehension as to its effect on plant equipment over a long period of time has been eliminated and present plans are to continue using it at Dearborn for at least another year.

In the introduction of this paper it was stated that the principal purpose for conducting this research work was to find a suitable substitute for the costly ferric chloride. This it is believed has been accomplished to the extent of effecting a saving of $1.50 per ton of dry solids, or a total of over $20,000 per year.

This paper has been confined to the use of pickling liquor for sludge conditioning. However, a great deal of work has been done using pickling liquor for chemical precipitation of sewage, on which it is hoped to report at an early date.

Acknowledgment

Grateful acknowledgment is made to the Ford Motor Company for its cooperation in furnishing the pickling liquor for the early trials; to J. E. Cooper and his staff for their invaluable assistance during 1947 and early 1948; and to the Murray Corporation for furnishing pickling liquor since November, 1948.

Appreciation is also expressed to Clem Glotzhober, Dearborn chemist, whose efforts contributed greatly to the completion of this assignment.

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DISCUSSION

By J. E. Cooper

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In commenting on Mr. Groen's interesting paper, it should first be pointed out that much of the initial success of the project should be credited to C. A. Habermehl and F. H. Burley, chemist and engineer-in-charge, respectively, of the Detroit sewage treatment plant.

Not covered in the paper is the interesting method used in evaluating the conditioning effect of the addition of various concentrations of pickling liquor to laboratory samples of sludge. The laboratory filtration procedure followed was that developed by Genter (1). After making a few modifications, this test was used in routine control of sludge conditioning at Detroit. The large measure of success which followed in the plant scale studies was directly a result of the many weeks of filter flask tests.

One of the interesting related studies was that made by Mr. Burley on the life of filter cloths during the plant scale tests at the Detroit sewage plant, which were carried on previous to and concurrently with those made at Dearborn. It is hoped that these studies will be reported at a future date by Mr. Burley.

In commenting on the reasons for the fact that adding the conditioning chemicals to the bucket elevators improved conditioning, it is interesting to look further at the similarity between ferrous and ferric hydroxide. In general, there is little difference in the physical characteristics of the two; the ferrous is blue (actually a mixture of ferrous and ferric), and the ferric is brown. Our laboratory studies have shown that the settling characteristics of each are about the same.

It should be pointed out that an important feature of the treatment is the lag in the hydrolysis and subsequent precipitation of the ferrous sulphate compared with ferric chloride. This lag can become very important when lime is used with pickling liquor as a neutralizing agent and the conditioning time is short, or the samples for pH control are taken from the conditioning tanks before the reaction has had time to proceed far enough. In such a case, a satisfactory lime addition based on pH would actually be too low, as the ferrous sulphate would continue to hydrolyze and consume additional lime after the samples were collected.

It is somewhat doubtful that the ferrous sulphate oxidizes to ferric sulphate as Mr. Groen reports. Rather, it is more apt to be the ferric hydroxide which would oxidize, and this only after the iron and sludge had been exposed to considerable air. As the sewage sludge is in itself a reducing mixture, the amount of ferric salts expected in the sludge is somewhat in doubt.

Concern was expressed in the initial studies at Detroit that the calcium sulfate formed would cause greater blinding of filter cloths than normally found. The solubility of calcium sulfate is quite high, however, and no such difficulties were experienced. This

may also be due to the tendency of the ammonia in the sludge to influence the solubility of the calcium salt.

A note of caution should be pointed out as a result of the earlier unsuccessful work at Dearborn using pickling liquor. At no time should the pickling liquor be added in such concentrations that the free sulphuric acid will liberate the odorous and potentially dangerous hydrogen sulphide. This is one of the main reasons for adding the lime first.

From an over-all standpoint, it would appear that raw waste steel pickling liquor, which is widely available from metal working industrial plants, steel mills, etc., can be used as a low cost substituted for ferric chloride in the conditioning of either primary or digested sewage sludge, with advantage to both the consumer and the producer. The work at Detroit and Dearborn is another example of the development of the use of an industry by-product when research teams combine efforts for the good of both.

Reference

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OHIO VALLEY DEVELOPMENTS

Permissible pollution limits in the Wabash River are being determined by the Ohio River Valley Water Sanitation Commission in the 100-mile stretch between Terre Haute, Ind., and Mt. Carmel, Ill. Work started in July, 1949, will provide the answer to what steps must be taken to curb both municipal and industrial waste discharges in this interstate waterway, a principal tributary to the Ohio River.

Authorization of this project, and the appointment of an engineering committee to report on the adequacy of sewage treatment measures proposed for the Huntington, West Virginia—Ashland, Kentucky—Ironton, Ohio, area of the Ohio River, occupied major attention of the Commission at its July meeting.

The Commission also approved the plans of the Allegheny County (Pa.) Sanitary Authority for the degree of sewage treatment required at Pittsburgh, pointing out that this would assure satisfactory quality where the river crosses the Pennsylvania-Ohio border. Prompt action was urged in the construction of the Pittsburgh treatment facilities, as these form a key element in the Ohio River clean-up campaign.

The Wabash River work is a cooperative interstate activity. Under the direction of the Commission's staff, it pools the resources of the states of Indiana and Illinois, along with federal agencies and private industry. From this industry will be informed precisely what treatment is needed to restore the stream to a satisfactory condition. Thus the corrective programs already underway by industries will be accelerated.

Robert K. Horton, sanitary engineer of the Commission's staff, is in charge of the survey operations. Representing Illinois is Clarence Klassen, state sanitary engineer. Indiana is represented by Blucher Poole, technical secretary of the Stream Pollution Control Board.

Stream Pollution

STREAM STANDARDS AND THEIR PRACTICAL APPLICATION *

By Charles C. Agar

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The purpose of this paper is to illustrate a possible approach to a sound solution of the very difficult problem of establishing stream standards and applying them in a reasonable and practical manner to specific situations where the capacities of streams to afford adequate dilution for sewage and wastes effluents are somewhat limited. At the very outset, it must be distinctly understood that the views expressed or values used herein are those of the author and should not in any way be construed as representing any fixed or future policy of the New York State Water Pollution Control Board or the New York State Department of Health.

The recently enacted Water Pollution Control Act creates, in the State Department of Health, a Water Pollution Control Board, consisting of the commissioners of the Departments of Health, Conservation, Agriculture and Markets, and Commerce, and the superintendent of the Department of Public Works. In the Act it is declared to be the public policy of the State of New York to maintain reasonable standards of purity of its waters consistent with public health, fish and wild life, conservation, and industrial development. The primary responsibility of the new Board may be summarized under two main categories: (a) prevention of any new pollution of state waters; and (b) abatement of existing pollution.

The Act further provides for the establishment of standards of quality of waters for various uses and the classification of the waters of the state in accordance with the best social and economic use thereof. This can be accomplished only after public hearings have been held and all parties concerned given opportunity to present their views and opinions. Contravention of the standards of quality established by the Board constitutes pollution of such waters and the Board is authorized to prohibit and regulate the discharge of any existing or potential pollutants. From the foregoing it can be seen that the term "pollution" is relative and must be related to the water usage. For example, pollution of a source of public water supply might not constitute pollution of waters so far as fish life is concerned.

Basis of Stream Standards

There must be developed, therefore, so called "stream standards" that can be used for the classification of the various waters of the State in accordance with their usage. All streams are not of the same quality; a situation in existence even before the advent of our present civilization. Waters from a small mountain spring have characteristics different from those of the mighty river at its mouth. However, with the development of urban life and the growth of industries, with concomitant discharge of sewage and industrial wastes into the waters, the characteristics of the stream underwent a marked change and progressive degradation. There is

* Presented at 1949 Spring Meeting, New York State Sewage Works Association; Kingston, N. Y.; June 6–7, 1949.

no major watershed in New York State today which does not suffer to a greater or lesser degree from the discharge of sewage or industrial wastes.

There are a number of ways in which standards for stream sanitation have been established in the past. The earliest standards in use may be referred to as limiting stream dilution criteria. These were usually expressed in terms of the number of cubic feet per second of stream flow necessary for each 1,000 tributary population, and varied with the degree of treatment provided. Such criteria obviously are inadequate, as they do not take into account stream use or stream capacity to receive and satisfactorily dispose of pollution.

Another standard frequently used today refers to the quality of effluents at their points of discharge into watercourses. Such criteria, again, omit all reference to stream use or capacity.

Offhand, it might seem much simpler to adopt and utilize effluent standards for a particular stream or watercourse. In such case, all industries and municipalities might be expected to treat their wastes to approximately the same degree. In the case of industry this would mean, for example, that the large and small plants alike might have to provide the same degree of treatment, regardless of their location on the stream or the amount of dilution available at their respective points of discharge. From the point of view of competition among similar industries this would put it on a more nearly equal basis, but would not necessarily be utilizing the absorptive capacity of the stream to best advantage in maintaining satisfactory conditions at the various points of usage below.

More recently, standards for the quality of the receiving waters—in reality a specification of the desirable qualities of the waters for particular uses—are being recognized as the most reasonable and equitable approach to pollution control. Under the last standard, permissible degrees of pollution are regulated so as to maintain satisfactory sanitary conditions in the stream, not only in the general interests of the public at large, but also for the needs of industries, recreation, agriculture, urban development, and other related factors pertinent to the region concerned. This system of stream standards is at least suggested by law for New York State, and will make it possible to classify the streams either in their entirety or by various zones on the same stream, consistent with the highest recognized use of such waters considering the best interests of all the people of the state.

It is evident that the use of the stream standard is a more reasonable approach to safeguarding a stream than is the use of arbitrary effluent standards. Standards for the stream itself permit the legitimate use of a natural resource and recognize the stream's capacity for assimilating and disposing of the wastes of community life. As long as a sewage or a waste can be discharged into a body of water without any adverse effect on the highest or best use to which the water may be put, there is no need for treatment. However, even aesthetic conditions involving such matters as offense to the senses of sight and smell may well become a logical reason for treatment. As a general rule all man-made pollutants or contaminants must be considered as requiring at least a minimum of treatment in order not to have an adverse effect on subsequent water usage.

Standards Only Guides

In discussing standards it should be remembered that they are not fixed for all time. They necessarily must be subject to modification as needs change. Civilization does not stand still. Standards must not be entirely inflexible, but should serve as a guide for a reasonable period of time. Any

stream standard, therefore, should be considered as an operational objective and should serve as a base line for planning purposes and for analyzing each problem of effluent discharge. Research and experience will dictate when and what changes must be made in the standards.

It is not unreasonable to expect that any stream standard adopted should serve as a guide for a period of 10 years, or longer. Just because the time period cannot be definite is no reason to assume that the standard does not have practical application. Any standards developed must be justifiable and equitable. Between the idea of a stream without any foreign materials whatsoever (that is, no man-made contaminants) and a stream which is so grossly polluted as to be a menace to health, or a public nuisance, there must be a reasonable condition of a stream which will best serve the interests of civilized life, the operation of industry, the maintenance of fish and aquatic life, and the general use of the stream in accordance with the classification finally adopted. Furthermore, this objective must be within the economic limits of taxpayers and industry to attain such a goal.

Reasonable and Logical Use

What is a reasonable and logical use of a stream for the disposal of wastes? A municipality or an industry does not by its mere existence acquire a right to discharge its wastes into the waters of the state. In addition to the riparian rights of downstream property owners, either private or public, it must be recognized that the municipality or industry has a moral as well as legal responsibility to prevent undue pollution of the waters. There must, however, be a reasonableness about any restrictions on the discharge of sewage and industrial wastes. Any standards adopted for particular streams must be not only technically attainable, but also financially feasible. There cannot be imposed on the state's industrial and municipal economy an expense which is out of proportion to the benefits sought. It must be remembered also, that the reasonableness of any standard is subject to review by the courts.

Tentatively, a possibility under consideration is to classify the fresh surface waters of the state in accordance with 5 general classifications—A, B, C, D, and E. Class A waters might include a natural runoff with no sewage or industrial wastes on the watershed; in effect, practically an unpolluted stream with little or no habitation on the watershed. The water would probably be excellent as a source of public water supply, fish propagation, recreation, and bathing, as well as for the use of industry, agriculture, and all other possible uses.

Class B might designate a zone of the stream on which there was some habitation and into which treated sewage and industrial wastes were being discharged. The class may be considered slightly polluted waters, good as a source of public water supply (with filtration and chlorination), for fish propagation, recreation, and bathing, and also for industry, agriculture, etc.

Class C waters might be a stream where there was considerable habitation on the watershed, with or without treatment of the sewage and industrial wastes (dependent on many sanitary factors). This could be considered a moderately polluted stream. Such a water might be thought of as tolerable, but poor as a source of water supply, for fish propagation, and for recreation. It would not be suitable for bathing. It might be suitable as a source of water supply for many industries without treatment, but pretreatment might be required for some industries. It could only be used as a source of public water supply after very complete treatment.

Class D waters might be those in which there was considerable pollu-

tion, a stream more or less allocated as its prime function for the disposal of partially treated sewage and industrial wastes, but treated sufficiently to prevent objectionable nuisance conditions. It would be unsuitable as a source of public water supply, unsatisfactory for fish propagation, but always within the tolerance limits for fish survival. It would be unsatisfactory for recreational use, and in some respects probably unsuitable for general agricultural use. It might be suitable for a few industries as a source of water supply for some processes, but primarily for use as cooling water. It should be satisfactory for navigation.

The last classification, E, would indicate a condition of gross pollution with nuisance conditions, including such matters as odors, sludge, tar, toxic substances, oil, etc. This would be unsuitable for all normal water usages, except possibly navigation, and even here corrosion and interference with navigation could well become a serious problem. This class of waters should not be tolerated and pollution abatement measures should be required.

In addition to the classification system for fresh waters it will be necessary to develop a similar system for ground, salt, and tidal waters in accordance with their various uses.

Stream Zoning

Assuming that the standards have been established for the various uses of waters and that the streams have been classified more or less in accordance with the foregoing principles, it is conceivable that in the upper reaches of a stream, such as in the Adirondack mountains, a stream could easily be given the highest classification. This would be the case if it is beyond the influence of man-made contamination resulting from human and industrial life. A lower region of the stream might be given a secondary classification and, similarly, the lowest reaches might be in a lower classification. This does not mean, however, that it might not be possible to have a stream where the reverse of this classification could not be applicable.

Under any scheme of zoning, it has been pointed out that the main disadvantage of a stream standard from the viewpoint of the individual polluter is the tendency to penalize unfavorable location on a stream. A municipality, for example, would be required to provide a higher degree of treatment for its sewage if located in a Class A zone of the stream than would another municipality in a Class C zone, which could "get by" with a lesser degree of treatment. The same general principle applies to industries under the same conditions.

It is true that location on a stream may in some instances penalize a particular polluter. Is that materially different from anyone having to pay higher taxes when he elects to live in a so-called "better neighborhood?" There also can be natural advantages to an industry because of nearby cheap water power or to a port because of a good harbor.

Why establish the same degree of treatment and quality of effluent for all industries? This would, in effect, penalize the industry located on a section or zone of the stream with lower classification by requiring a higher degree of treatment than necessary. After all, the reason for any treatment is the condition to be maintained in the receiving stream; not to put all industries on an even competitive cost basis for treatment facilities. To illustrate the principle involved, certainly a tannery planning to locate on a watershed of a public water supply should expect to pay more for waste treatment than a similar industry located on the canalized Mohawk River. In one case the water is used primarily as a drinking water supply and would naturally fall in the highest classification; in the other, the waters are used primarily for navigation and the disposal of

sewage and industrial wastes without nuisance. True, recreation, fish, etc., are in the picture, but they would not likely be the major factor in classifying the latter stream as to its best social and economic usage.

Minimum Effluent Standard

As shown above, there cannot be one stream classification for all the waters of the state. It follows that there cannot be one effluent standard applicable for all the waters of the state. Nevertheless, there can be for effluents a general minimum standard, which is dictated by reason, logic, and the requirements of common decency. Such a statement, of course, must not be considered inflexible or at this time in any way representative of the policy of New York State. It is suggested, therefore, that something like the following might be considered minimum objectives as applying to most waters of the state:

1. Practically complete removal of settleable and sludge-producing solids.
2. Removal of floating solids and practically free of visible oil and grease.
3. No free acid or alkali (pH range 5.0 to 9.0).
4. No chemicals or other materials in quantities resulting in concentrations toxic or inimical to man, fish, or normal aquatic life after admixture with the receiving waters.
5. Reduction of oxygen demanding materials (B.O.D.) so that resulting dissolved oxygen (D.O.) in the stream is maintained above 5.0 p.p.m.

The above may be considered generally as possible minimum (and at present unofficial) objectives in order to maintain most streams (varying with dilution factors) in Classes A, B, C, or D. Further requirements will usually be necessary for assurance of maintenance of the higher classifications of streams, particularly in the Class A and B zones.

Once having established the classifications of a stream, the application and use of this standard in particular instances can well be the next step. From the stream standard can be determined the quality of effluent required or the total quantity of contaminants permissible without adverse effect on subsequent water use or use of the stream below. It is expected that certain contaminants might have to be practically zero in the effluent of a plant, whereas others are readily assimilated by the stream, making use of a part of its capacity, but always reserving some capacity as a factor of safety.

Allocation of Stream Capacity

If there is only one source of pollution on a stream, it is a relatively simple matter to determine what the character of an effluent must be in order to maintain the stream classification. The dilution factor, together with the assimilating power of the stream, can be simply applied to assure that the stream will be properly maintained during periods of both high and low stream flows.

But what if a second or third industry or municipality is also involved? In the course of a stream survey it should be possible to determine the "zone of influence" of all polluting materials. The zone of influence can be considered as that distance or length of stream beyond which the uses to be made of the stream are not affected by any particular contaminant. With the condition of the stream and its usages as the paramount considerations, it is possible to determine what the characteristics of various effluents within the zone of influence must be. This, in effect, means that the quality of plant effluents must be determined and

that in making the determination consideration should be given to the other sources of pollution on the stream. What method is to be used to determine what the quality of effluent from a particular plant should be?

Without attempting to set up any inflexible or exact formula it would be well to discuss the principles of a possible solution of this problem—a solution believed to be both fair and equitable to all parties concerned. Let it be assumed that in a particular stream 70 per cent of that stream's capacity for absorbing wastes is available for the dilution and disposal of sewage and industrial wastes. The remaining 30 per cent of the stream's capacity is reserved as a factor of safety and for expansion and growth over a possible 10-year period. The 70 per cent of the stream's capacity can then be allocated among the various sources of pollution so that each will be entitled to a fair and reasonable part of the stream's capacity for use in disposing of plant effluent without contravening the standards set by the stream classification. In actual practice this could be worked out and an effluent standard established for each specific source of pollution.

In order that this hypothetical allocation is arrived at in a reasonable and equitable manner there are many factors which must be taken into account in addition to population and the volume and strength of the polluting material. It may be possible to develop a formula which will take into account, for example, in the case of industry, such factors as assessed valuation, local taxes, number of employees, amount of payroll, value of products and others which will give a picture of the economic value of the industry to that particular area and to the state as a whole. Such information will also be needed for the initial classification of the stream. By giving some recognition to relative economic values it should be possible to apportion the 70 per cent of absorbing capacity or volume of a stream among any number of possible pollution sources.

To illustrate further the plan involved, a relatively simple problem will serve as an example. This is an entirely hypothetical case and the values used should not be construed as representing any official or set policy, as such values might be markedly different in an actual application. The main point in working out an example is to show the simplicity and logic of some formula that will recognize economic values.

Let it be assumed that a water pollution survey has been made along a large stream, which is used at one point as a source of public water supply. The stream has been classified in a category which will protect it as a water supply source. There are located on this stream several industries, three of which have been determined from the survey to be responsible for the discharge of phenol, which is practically the only pollutant affecting the quality of the water supply some 30 or 40 miles below. The stream survey has further determined that the maximum and most far-reaching effect of phenol, producing taste and odors, occurs during the winter season. Therefore, from the point of view of this particular pollutant—phenol—an analysis for allocation of the stream's absorption capacity should be based on winter flow conditions.

It is assumed, also, that the three industries are entirely different in their operations, but that all have phenol in different amounts as a component of their liquid wastes discharged into the stream. Furthermore, the survey has developed satisfactory information from each industry on the volume of flow, the amount of phenol discharged, the number of employees on the payroll, the assessed valuation or local taxes, and many other factors relating to the plants. Only a few of these

factors need be used to illustrate the problem.

Table I shows how a reasonable allocation of the stream's absorbing capacity might be developed. It will be noted that if allocation was on the basis of volume, industry C would be entitled to use 92.5 per cent of the flow and industry A only 0.5 per cent. However, if determined on the basis of phenol discharge per day, industry B might expect 61 per cent of the stream available for dilution. It will be noted that relative weights of importance have been arbitrarily assigned to the factors of volume, employees, valuation, and phenol. Using these factors as shown in the table, an allocation of 11.5 per cent is arrived at industry A, 22.2 per cent for industry B, and 66.2 per cent for industry C.

For purposes of simplicity in this example the volume of stream flow is used as the numerical indicator of the

TABLE I.—Illustrative Analysis of Stream Allocation for Phenol Wastes

(a) Data for Three Industries Within the Zone of Influence

	Industry A	Industry B	Industry C	Total
Waste flow (m.g.d.)	0.1	1.5	20.0	21.6
Employees (or payroll)	250	200	1,200	1,650
Assessed valuation (or taxes) ($)	1,000,000	2,500,000	11,500,000	15,000,000
Phenol discharged (lb./day)	200	500	120	820

(b) Allocation on Individual Basis

Basis	Industry A	Industry B	Industry C	Assumed Rel. Wt.
Volume (%)	0.5	7.0	92.5	20
Employees (%)	15.2	12.1	72.7	30
Valuation (%)	6.6	16.7	76.7	30
Phenol (%)	24.4	61.0	14.6	20

(c) Allocation on Relative Weights

	Industry A	Industry B	Industry C
Volume	0.1%	1.4%	18.5%
Employees	4.5%	3.6%	21.8%
Valuation	2.0%	5.0%	23.0%
Phenol	4.9%	12.2%	2.9%
Allocation	11.5%	22.2%	66.2%

(d) Allocation Applied to Stream

Stream flow (min. winter) (c.f.s.)	10,400
Flow assumed for allocation (70%) (c.f.s.)	7,300
Permissible phenol conc. (assumed) (p.p.b.)	5.0
Maximum phenol per day (lb.)	200

(e) Allocated Phenol Discharge per Day

	Industry A	Industry B	Industry C
Weight (lb.)	23.0	44.4	132.4
Concentration (p.p.m.)	28.0	5.3	0.8
Volume (m.g.d.)	0.1	1.5	20.0

absorptive or assimilating capacity of a stream. This factor could just as well have been oxygen resources and reaeration capacity, or such a capacity as its potential power of biological stabilization or assimilation. Time of flow to the point of highest classified usage could also be a consideration.

The minimum flow in the stream during the winter season has been assumed to be 10,400 cu. ft. per sec. and it is assumed that 70 per cent of this flow is available for dilution, or 7,300 cu. ft. per sec. An assumption must be made also for the permissible phenol concentration in the waters to be used as a source of public water supply. This would be determined by the standards established for this water usage. A value of 5.0 p.p.b. is assumed for purposes of the example. This, then, gives 200 lb. as the maximum allowable amount of phenol which could be discharged into the stream uniformly during any one day. Applying the allocation on the relative weight basis it is found that industry A is restricted to 23 lb. or less of phenol; industry B, 44.4 lb.; and industry C, 132.4 lb.

How would this affect the operations of these three plants? Industry A is discharging 200 lb. of phenol per day. This is a high concentration in a 100,000-g.p.d. flow. A phenol recovery plant, or some other form of treatment, would be necessary to reduce the phenol discharge 90 per cent or more. Possibly good housekeeping within the plant might effect a marked reduction in phenol losses. In reference to industry B, which is losing 500 lb. of phenol per day, a phenol recovery or other treatment plant would be necessary to reduce the phenol discharge to less than 44 lb. per day. Considerable factors of safety would necessarily have to be incorporated in the design of any such installations.

In regard to industry C, it will be noted from the example that the permissible phenol discharge is more than that currently being discharged. The survey disclosed that phenol sources in this plant were many in number and all in very low concentrations. Treatment or recovery was considered uneconomical or unnecessary in view of the amounts and concentrations involved. Therefore, this plant might not have to provide any further treatment for phenol wastes.

An objective will always be to further reduce the amounts of losses and provide a higher degree of recovery or treatment as new methods or processes are developed. Here again, research and experience will indicate when higher standards are feasible and within reasonable economic limits related to the benefits to be derived.

If at any time it is found that the effluent standards established are having an adverse effect on the receiving stream at the points of normal usage, the standards could be re-evaluated in the light of the changed condition. However, it should be possible to set up a standard on at least a 10-year basis, particularly with the unallocated reserve capacity of the stream as a factor of safety.

In most cases this allocation should be made on the basis of low or drought flows occurring frequently. It is believed unreasonable to base a standard on a drought condition in the stream which occurs only once in 10 to 20 years. Again, a high degree of treatment need not necessarily be continuous throughout the year. If the need is for a higher degree of treatment during the summer or drought season —or for protection of some particular use of the stream, such as bathing during the summer season—it is considered reasonable that the degree of treatment might be varied seasonally, but only after proper study and approval of such modification of treatment has been granted.

It cannot be expected that passage of the New York State Water Pollution Control Act will effect any immediate correction of the present pol-

luted condition of many of the State waters. It took years for the streams to become seriously polluted, and correction of the pollution cannot be carried out overnight. It is expected that the process of pollution abatement will become a long range program carried out progressively as streams can be surveyed and classified over a period of the next 10 years.

During this interim period the Act provides that the Conservation Department law relating to pollution remain in full force and effect until January 1, 1960. Likewise, the State Commissioner of Health is given continued responsibility for the regulation and control of pollution under Sections 74 through 87 of the Public Health Law, which are not finally repealed until April 1, 1959.

It is hoped that the foregoing will stimulate discussion of this concept and recognition of a principle that can be applied practically in a water pollution control program.

POLLUTION CONTROL BOARD RECOMMENDATIONS

The recently organized Water Pollution Control Advisory Board (THIS JOURNAL, **21**, 2, 552; May, 1949) at its second meeting in October adopted recommendations to assist the U. S. Public Health Service in carrying out its far-reaching program to improve and safeguard the nation's water resources.

In its report to Surgeon General Leonard A. Scheele, the Board recommended a firm policy to insure abatement of pollution of interstate waters, as well as preparation of the "essentials" of a uniform state law which could be adopted in part or in whole by states interested in strengthening their water pollution control activities. Among other steps taken during the recent two-day meeting the Board recommended adjustments in the formula used for allocation of grants to States for studies of industrial waste pollution of waterways.

The Board also endorsed continuation of special grants for study and research projects having sectional or national significance and suggested that preference be given to projects in which industry cooperates by supplying funds or skills. This action reflects the Board's belief that the solution of industrial waste problems in the nation's waters is primarily the responsibility of industry.

Atomic energy implications of the Water Pollution Control Act were brought to the Board's attention by Chairman Mark D. Hollis, Assistant Surgeon General, who explained that inasmuch as radioactive wastes in streams are pollutants, plants producing them come under the authority of the Water Pollution Control Act. In view of security requirements, however, this problem must be handled in close collaboration with the Atomic Energy Commission.

The Board concluded its policy-making recommendations by adopting a motion that the Public Health Service encourage formulation of uniform methods of waste analysis among the various professional technical organizations engaged in water, sewage, and industrial waste activities.

PERMISSIBLE WATER POLLUTION AT COMBINED SEWER OVERFLOWS

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With regard to its origin and duration, stream pollution caused by sewage discharged from communities with combined sewer systems or duplicate systems can be divided into two categories. On the one hand, continuous water pollution occurs due to the sanitary sewage outflow (which may be assumed as treated in some way), the variations of which depend primarily on those of the runoff in the stream, and generally to a lesser extent on those of the pollution load. On the other hand, due to the storm-water flow, an intermittent water pollution occurs having a relatively short total duration and large variations, both usually influenced to a greater extent by the variations of this pollution load than by those of the runoff. Thus, the duration of the storm-water pollution will be indicated by a steeply falling curve, a fact which must be considered when establishing permissible water pollution, as does also the difference in origin compared with the first category

During the attempt to work out a method for computing the required regulated flow—that is, the necessary amount of storm flow in a combined trunk sewer to be diverted for disposal (20), including the computation of the quantities and variations of water pollution caused by discharged storm flow—it was concluded that it was necessary to study the question of formulating permissible water pollution. The points of view which should be taken into consideration in this respect will be discussed subsequently. Also, the method of expressing permissible water pollution will be illustrated, on the basis of the conditions mainly prevailing in Sweden.

It must be emphasized that the views presented herein essentially concern the principles involved in the question, and not the absolute values of permissible water pollution. The latter is a matter for regulatory authorities. Moreover, opinions as to most suitable limits of permissible water pollution, especially in hygienic respect, can be expected to vary considerably (7) (13) (15). The intended use of the stream or lake, which can often depend on a comprehensive technical and economical consideration, is also of importance (7) (8) (10) (11) (15) (17) (18) (19). There may, however, be reasons for presenting in this connection a leading principle as to the degree of permissible water pollution. To the author it thus seems desirable that streams and lakes in general—excluding strictly defined exceptions; for example, according to a special water pollution abatement program—comply with such requirements of natural purity as to be suitable not only for aquatic life, but also for recreation, especially bathing. In addition, it should be possible to use streams and lakes for watering domestic animals and for the production, through comparatively simple means, of suitable drinking water (for limited requirements). Such a principle may be accepted in the United States, if not wholly at least widely, but in a majority of other countries it is not yet widespread.

Formulation

The purpose of water pollution abatement, in consideration of what

has been said, cannot be that a certain limit must never be exceeded (1). Ignoring the fact that requirements can change from case to case (8), this would involve too strict a standard, which not only would lead to practical and economic impossibilities, but could also be theoretically unreasonable. Most standards which are established for water quality, whether concerning raw or potable water, are so formulated that they state not only a certain limit for average conditions, but also a certain upper limit which is permitted during a certain relatively short total time (12) (15) (16). It seems that criteria for water pollution, in general, ought to be stated so that the shorter the time of duration, the higher the limit value could be fixed. Concerning a relatively long duration, however, this increase ought to be very moderate, even with a relatively great variation of time. On the other hand, in considering short duration (exceptional conditions) a substantial increase of the limit ought to be permitted in comparison with the order of the value for long duration. The increase may rise rapidly as time approaches zero.

This reasoning leads to the conclusion that the limit value for permissible water pollution ought to be stated in principle, as a duration curve of hyperbolic form with asymptotes parallel to the coordinate axes. In practice, however, it may be enough to give a few points on this basic curve. Examples of such duration curves will be presented in the following.

The purpose of the following examples dealing with duration curves for permissible water pollution is, as mentioned, to illustrate the principles stated, but not to propose absolute values. The given values are chosen, however, so that they coincide with the author's opinion as to what is most suitable for Swedish conditions in general—that is, when no special circumstances are involved. In this connection attention is drawn to the fact that these curves are to be considered as distribution curves and thus denote total (or summarized) duration for any concentration of pollution, and not a continuous period of time during which this pollution is reached or exceeded. Furthermore, the terms chosen to express permissible water pollution, mainly originating in residential areas, are not considered to be the only suitable terms (8) (13). They are, however, in agreement with the opinions presented in another paper by the author (21) on the relation between the amount of added pollution load and the resulting water pollution. That paper also defines more fully the concepts here used of water pollution in biological and in hygienic respect, the first primarily concerning aquatic life, and the second constituting a menace to public health (9) (13). Thus, residual dissolved oxygen content (or oxygen deficiency) as an indication of water pollution in biological respect, and density of coliform bacteria in hygienic respect are considered to be the most important terms for expressing water pollution standards, and particularly those which can best serve as a basis for calculations.

Duration Curves

General Aspects

Certain general principles may be stated for the determination of duration curves for permissible water pollution. Thus, for a relatively long duration, the curve should approach the established limits for average permissible water pollution. For a relatively short duration the curve ought to be drawn with particular regard to the previously mentioned upper value (in general permitted for a limited time only), as well as to the degree of pollution due to discharged storm weather flow. This latter category of water pollution must be in addition to other existing pollutions (13).

The duration curves by which the proposed formulation for standards of permissible water pollution is illustrated, are drawn, as previously mentioned, with special regard to conditions generally prevailing in Sweden. Furthermore, they refer to the warm season of the year, particularly to the months of July and August. These months have been chosen because the risk of gross water pollution is greatest during this time, particularly that water pollution due to discharged storm weather flow. This depends on the fact that, for generally prevailing conditions, the runoff in streams is at a minimum during July and August, but the temperature and precipitation are at a maximum. The duration curve for resulting initial water pollution in a stream due to storm weather flow discharge is presented in another connection (20) and special consideration must be given, therefore, to the course of the curve, which is produced by means of probability calculations, beginning with duration curves for sewage flow, rain-water flow, and stream runoff, the basis being the period of time July–August. In other localities the period of time which is to be used as a basis for the construction of a duration curve for permissible water pollution should be established, in each case, in the light of climatic conditions.

It seems reasonable that the upper limit mentioned may not only be equaled, but actually exceeded, during a considerable part of the total duration over which pollution due to discharged storm weather flow takes place. Discharge does not take place in all occasions of precipitation. Under these particular conditions, this total time, averaging around 20 hr. during July–August (corresponding to about 50 to 60 hr. during a normal year), is divided among some dozens of rainstorms. The period of service for storm overflows thus averages less than 1 hr. per time of discharge. Exceeding the upper limit during half the time of service, or altogether about 10 hr. during July–August (around 20 hr. during a normal year) seems, on the one hand, to be permissible. On the other hand, it is not of great importance if, at least theoretically, even very poor conditions should arise during an average of a few minutes at each occasion of discharge; that is, normally a few hours total during July–August. Furthermore, for the present at least, these duration curves should be given in as simple form as possible.

Biological Considerations

Permissible water pollution, from a biological viewpoint, seems generally to be so formulated that it is desirable to maintain the dissolved oxygen content above 5 p.p.m.; for any noticeable length of time the dissolved oxygen content should not remain below 4 p.p.m., and it must not fall below 3 p.p.m. (4) (6) (10) (12) (13) (14) (15). The duration curve in Figure 1 has been constructed with regard to this and to what has been previously related. This curve expresses primarily residual dissolved oxygen content, O, in p.p.m., as well as in per cent, the latter assuming an oxygen saturation of 10 p.p.m. Secondly, oxygen deficiency D, is also noted, in p.p.m. and in per cent, computed for the stated oxygen saturation. The curve for permissible oxygen deficiency consists mainly of a logarithmic straight line having a value of 70 per cent (corresponding to 3 p.p.m. on the curve for required dissolved oxygen content) at about 4 hr., 60 per cent (content 4 p.p.m.) at about 13 hr., 50 per cent (content 5 p.p.m.) at about 50 hr., and at about half the period (corresponding to a lesser part of the whole year) the value of 35 per cent deficiency (content 6.5 p.p.m.).

However, the oxygen deficiency (21) can generally be considered as directly proportional (at least approximately and sometimes after certain

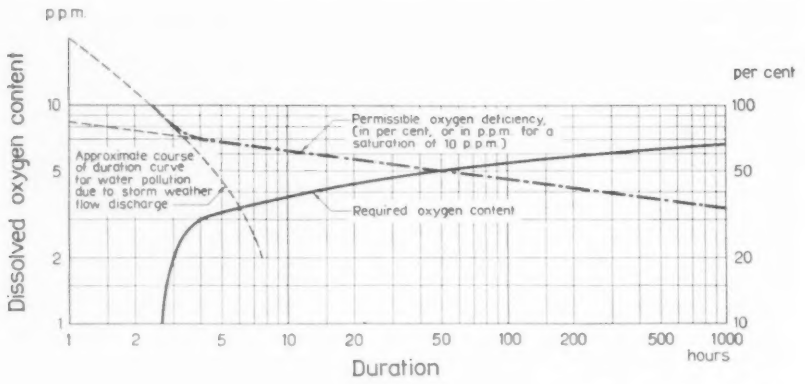

FIGURE 1.

converting calculations) to the initial oxygen demand in the recipient water body, L, caused by the added pollution. This as a rule, allows for direct comparison between the course of the permissible water pollution curve of Figure 1 and that of the previously mentioned duration curve, expressed in oxygen demand, for resulting initial water pollution in a stream due to discharged storm weather flow.

The duration curve for water pollution due to storm weather flow discharge has, as shown in Figure 1, a decidedly steeper slope than the curve given here for permissible water pollution. To attain a reasonable result when the latter curve is applied in practice, it is therefore necessary, up to a certain quite short duration—even if the procedure implies going in a circle—either to neglect the existing pollution, or, which is the same thing, allow the curve up to that duration to assume a steeper slope. Here, the latter course has been chosen. The curve for oxygen deficiency for an average total duration of about 2.5 hr. (corresponding to 3 to 4 hr. yearly) has been given a value of 100 per cent (oxygen content O p.p.m., theoretically). Immediately thereafter it has the same form as the curve of pollution referred to, and afterward it gradually approaches the straight line. Thus at 3 hr., a duration which for many reasons has been selected as the definition duration for water pollution due to discharged storm weather flow, the curve indicates a permissible oxygen deficiency of 80 per cent (required content, 2 p.p.m.). It should be noted not only that a certain duration is derived from several occasions of precipitation added together, but also that equalizing factors will be present. In reality, the duration for such a low oxygen content as zero or slightly above, when due to storm weather flow discharge, becomes very short or reaches zero. Further, it may be mentioned in this connection that, because the pollution considered here mainly originates from municipal sewage, the water pollution in hygienic (and not in biological) respect will usually be dominant (1) (9).

Hygienic Considerations

As has been stated, opinions on the hygienic aspects of water pollution vary a great deal. This is true not only concerning standards for bacterial density—for example, in bathing areas—but also concerning more general principles for the use of lakes and streams. As regards the latter, the aforementioned principle will here be

followed; that is, primarily suitability of the water for bathing.

In this connection it ought to be pointed out that the bacterial density does not always give an accurate picture of the concentration of sewage in a recipient water body. This is particularly the case when the effluent from a purification plant has been chlorinated. True sanitation requires due regard to this fact when judging water pollution (9); for example, by comparison with the prevailing oxygen demand.

By means of a purification process with multiple lines of defense in hygienic respect, it is considered that satisfactory drinking water can be produced from raw water containing 10 to 100 coliform organisms per ml. (14). With a purification process based on only one single barrier, a substantially lower bacterial density is required, on the average not exceeding about 1 coliform per ml., and occasionally 5 to 10 times more (2) (3) (13) (14). These latter values seem to nearly correspond to those standards which are generally established for bathing areas (5) (7) (10) (12) (13) (15), and they should thus be approximately suitable from the hygienic viewpoint.

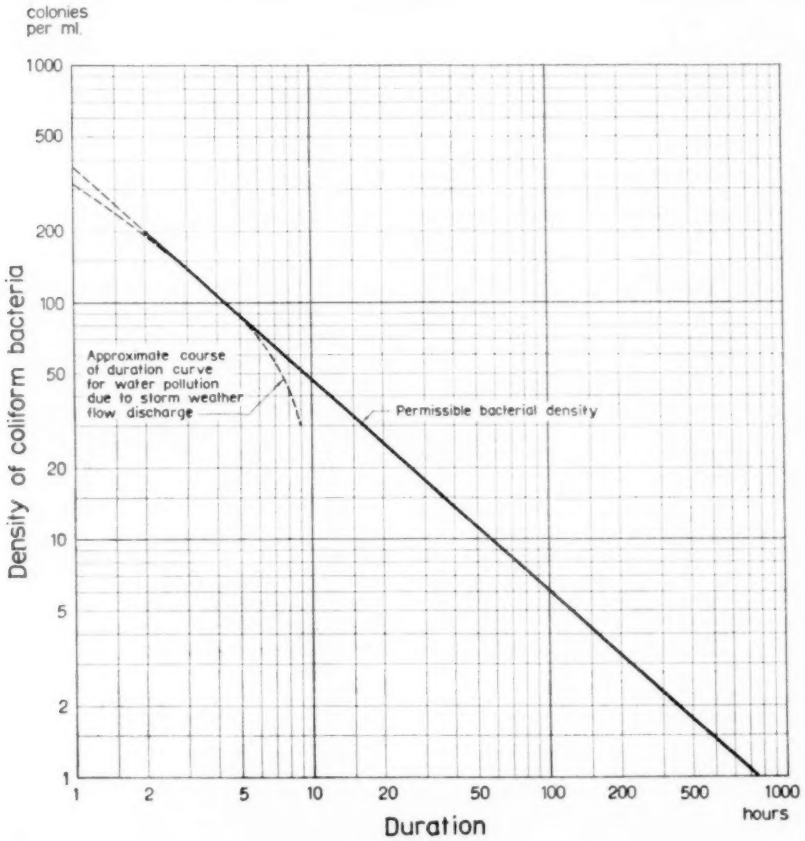

FIGURE 2.

The curve in Figure 2 has been selected so that the permissible bacterial density for a total duration of about 25 hr. during July–August normally amounts to 20 coliform organisms per ml.; for a total of about 60 hr., 10; and for half the period, 1. The duration curve is seen to consist of a straight line in a double logarithmic diagram and permits a water pollution of about 40 to 50 coliforms per ml. for a total duration of 10 hr., and, theoretically, for a total of 3 and 2 hr. about 150 and 200 coliforms per ml., respectively. The curve has a slope so steep and so close to that of the duration curve of storm weather flow discharge, particularly in the vicinity of the aforenamed definition duration of 3 hours, that any deviation from the straight line with regard to the latter curve need not be considered. It should be mentioned in passing that it does not seem unreasonable to raise the curve somewhat, especially for long duration (7) (12). Moreover, for short duration it may be found economically necessary to permit a raising of the curve.

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THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

USE THAT ORDINANCE MANUAL—NOW!

Recent distribution of the Federation's Manual of Sewage Works Practice No. 3, entitled "Municipal Sewer Ordinances," marks what is hoped to be only the beginning of a long and constructive career for the new publication. How successful it is will be determined by the use to which the manual is put by sewage works superintendents.

The first step is to bring the message of the ordinance manual to the attention of the proper municipal officials. The manual can do no good on an office bookshelf. It is not the collector's item to be admired and not used. It must be made to speak for itself and for you. As a recent editorial* puts it, "The sewer ordinance manual will more than justify its production if it does nothing more than remind municipal officials either that (a) no sewer system regulations are in force, or (b) that existing regulations should be reviewed and brought up to date. Consequently, Mr. Superintendent, you will do well to see that copies of the manual are read by the influential members of your Council, Commission, or Board of Trustees. He who heeds not this advice has no right to complain henceforth about how much of what comes down from this or that factory to upset his sewage treatment plant!"

Good advice; but just seeing that the right people read the manual is still not enough. The idea of an ordinance regulating sewer use must be impressed on the Council, not as an abstract matter affecting some other community, but as a concrete local need. The selling points, of course, are your own problems that have resulted from lack of the very ordinance proposed.

When the Council does decide to go ahead with an ordinance, guidance must be furnished for the selection of qualified ordinance committee personnel, and when such a committee is formed the superintendent must be prepared to move things along with positive, whole-hearted action. After all, it is his raw product that is being specified, as well as the manner of its delivery. To accomplish these things requires not only a detailed technical knowledge of his system and its limitations, but also of its ultimate capabilities. Here is a place where experience counts, and where the records we have written about so often in these columns will more than pay for the time and effort expended in compiling them.

Enactment of a new or revised sewer use ordinance will not relieve the superintendent from his responsibility toward it. In fact, his responsibility is just beginning. Even if not actually named to administer the ordinance he must, in his own interest, apply himself persistently toward just enforcement of whatever regulations are in effect.

The manual is at hand. Whether it accomplishes all that it is meant to depends on you, Mr. Superintendent. Will your copy be clean and unused in its niche on the shelf? Or will it be thumb-printed, dog-eared, and full of marginal notes, indicating that you and your Council have really used it?

H. P. O.

* THIS JOURNAL, 21, 5, 922 (Sept., 1949).

ACCIDENTS DON'T JUST HAPPEN *

By Ben H. Barton

Chief Operator, Sewage Treatment Plant, Findlay, Ohio

This paper does not presume to cover the entire field of safety in the treatment of domestic and industrial wastes. That has been done in several comprehensive works, among which are the Federation's "Safety Manual" (1) and the Ohio Department of Health bulletin on gas hazards (2), both useful guides for the safety-minded person in the waste treatment field.

The many publications on the topic of safety in waste treatment plants indicate, to some extent, the importance of safety. Few persons question the need for safety programs, safety appliances, and safety training in public life or in industry. The main point of disagreement seems to be not "why," but "how and when."

Most papers on safety seem to consist of lists of the hazards and their respective antidotes. The method infers acceptance of waste treatment plants as they presently exist and making them do. However, this is the wrong approach: the time to write off potential hazards is during the design stage.

The outstanding cause of accidents in existing types of sewage works is the lack of understanding of the potentials involved. There has never been a serious or fatal mishap in sewerage work that could not have been avoided had the accident factors been given due consideration. Accidents require lengthy preparation and three components—(1) the scene, designed by engineers; (2) an active ingredient, supplied by sewage; and (3) the individual, who completes the cycle. Design safety factors may be changed or additions made by the operating personnel to suit some particular need or fancy. The result may prove to be a hazard which the operator never suspects until it is too late, and which would never have been approved by the designer. Long experience and intelligence are prime requisites to detect the presence of accident potentials in advance, assuming that knowledge of engineering principles is available.

Educational training along specific operation lines will do more to prevent accidents causing damage or injury than will all the codes, ordinances, and safety inspections that could be drawn, although there is great need for such regulations. Even a smart operator can avoid accidents in an improperly designed or imperfectly functioning treatment plant only so long as his fellow workers cooperate fully. A carefully kept and factual record of operation will keep everyone up to date on plant activity. Accuracy is vital to safety.

Recommendations Must Bear Weight

There is need for state safety inspection of sewage and industrial waste treatment plants, but by specialists in certain types of plants rather than according to the ordinary workshop inspection routine now in effect. Nevertheless, no amount of inspections and inspection reports will supplant the need for intelligent functioning of operating personnel and there is no particular merit in making recommendations unless those in authority are required to follow them.

The approach to safety in waste treatment plants may lie in certification, not only of the operating personnel, but also of designers, technical supervisors, and state inspectors, in a manner similar to the professional

* Presented at 23rd Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cleveland, Ohio; June 22–24, 1949.

engineers' law but with the requirement that their safety recommendations are mandatory. Even with mandatory safety recommendations the accident rate will drop toward, but not to, zero. Nothing will stop the swashbuckler with the strong back and the weak mind (and his imitators) from injuring himself and endangering others in his brave impetuosity.

It is highly significant that the majority of fatal sewer accidents occur in small municipalities having no facilities for sewage treatment. Perhaps the village superintendent should be certified. As this was written a local sewer cave-in on a church property killed one man and seriously injured another as they removed shoring from a trench. News pictures indicated the sheathing was inadequate.

Safety a Management Function

Analysis of accidents in large plants shows, without exception, that somewhere in the chain of events there has been transgression of basic safety rules, either by the victim or by those in authority. In any event, the responsibility falls on the man in authority for lack of operator training or for failing to detect and correct a hazard either of his own accord or at the suggestion of the operator, who may become the victim while trying to surmount a reported danger. In some cases a lawyer could even establish criminal neglect.

Failure of municipalities to provide a comprehensive sewer ordinance is definitely a sin of omission. The Ohio Department of Health has distributed copies of the Detroit (Mich.) ordinance controlling the use of sewers as an educational gesture. It appears that a majority of sewage workers are more or less familiar with the provisions of this ordinance but that municipal councils are not.

Ten major hazards in sewage and waste treatment are as follows:

1. The individual, with his vagaries of thought and action.
2. Gas and matter of gaseous nature.
3. Electricity and electrical devices.
4. Inflammable or explosive liquids.
5. Insecure walkways.
6. Inadequate lighting.
7. Mechanical devices.
8. Inadequate supervision.
9. Improper design.
10. Neglect.

The list is not complete nor are the items necessarily listed in their order of importance. Each category overflows into other categories, but it is believed no one will question that the unpredictable individual is the number one hazard wherever he may fit into the picture.

Second place goes to the uninformed individual, who ignores odors, deems it unimportant to wash thoroughly, neglects making proper and complete entries on the operating log, and fills the log sheet with inconsequential items to prove how good he is. These defense mechanisms are an unfailing index of unsure workmanship.

The "individual" classification includes the citizens who dump live cartridges into the garbage to be ground in a hammermill; the boys who walk the tank walls and throw debris into the sewage; the tots who play around sludge lagoons; their parents who permit them to wander so far afield; the parents who condone continuing hazards; and all who complacently believe that safety is some other person's job.

Without exception, gas is the greatest impersonal hazard in sewage treatment. If it is remembered that gas is without independent form, shape, or volume; that it tends to expand indefinitely; that it is usually invisible; that it is sometimes odorless; that it is sometimes toxic; that it may be combustible; and that it may not support combustion or life, some progress will have been made toward safety in treatment plants and in sewer work. All

sewer and sewage workers must learn that organic matter always decomposes with the evolution of varied gases under proper conditions. An unventilated sewage structure will always contain some gas and must be ventilated before it is safe to enter. This must be remembered every time and even under seemingly safe conditions there must be adequate help standing by to assure the safety of the worker, who must have a safety line securely attached so that he may be hoisted from danger in an unconscious state. Perhaps state legislation would preclude fatalities by regulating sewer work through safety rules. Certainly it would be wise to examine applicants for certification as water or sewage plant operators on safety procedure and accident prevention, as well as on treatment lore.

Complete and concise information on gas is available in the literature and is beyond the scope of this paper. However, the thought occurs that there may be a hazard in the trend toward the use of glass block in waste treatment buildings. Ordinarily, in event of explosion within a building, breakage of window glass will disperse or release the force of the blast and minimize the ensuing damage. Can one imagine a designer considering this possibility without giving sharp scrutiny to the gas devices? Designing a sewage plant with break-away walls, such as are used in the manufacture of explosives, is a foreboding thought, but there have been cases where such a structure would have saved considerable replacement costs.

The only safe rule for handling methane gas is to keep it under pressure, which also means to prevent leaks. Pressure regulators of the diaphragm type are a fertile source of hard-to-find leaks, which are insidious because they occur so rarely that few operators have experienced them. The vents provided should be extended outdoors. Three factors—gas, air, and spark—are required to ignite or, in an enclosure, to explode. These seldom attain in proper proportions of gas and air, which is a good thing with so many sources of spark extant. Non-arcing switches are a minor step in the right direction. As a research measure the writer challenged an activated sludge panel to "make your plant bulk" with the idea that if the cause were known the cure might be found. There is no challenge here to set the stage for an explosion, but it is presumed to be as difficult as making activated sludge bulk at will, especially when a building is used as the combustion chamber. Nevertheless, such explosions occur.

The important reason for mentioning chlorine here is to acknowledge the deep debt of gratitude that water and sewage men owe to the manufacturers of chlorine and chlorine appliances for their concise directions for using chlorine safely. The continued use of so dangerous a gas as chlorine in thousands of installations by all sorts of persons is proof of the fact that once a hazard is recognized and properly approached there need be no accidents when reasonable precautions are used. When chlorine is involved in a mishap, invariably there has been dereliction of duty or inexcusable carelessness. No one can say that he "didn't know it was loaded."

Explosive liquids discharged to the sewers will be a constant source of danger, which cannot be entirely avoided, but which can be regulated with a proper ordinance and wise enforcement. Foam type fire extinguishers should be available to sewage personnel at all times. The hazard is aggravated within a closed place and mechanical ventilation does not suffice for explosive liquids where sewage carrying them enters a closed chamber. Safety indicates that the sewers have adequate vents upstream from the treatment plant. In the summer of 1948, at the Columbus Grove, Ohio, sewage treatment plant, gasoline fumes

apparently were ignited by the arc of a switch as the operator opened the screen-room door, which actuated the mechanical blower to ventilate the room. Thus, paradoxically, a safety device was instrumental in causing injury to the operator who suffered burns so severe that he has been granted total disability by the state. In April, 1949, the city of Marion, Ohio, sustained its second sewer-wrecking explosion, presumably from wasted gasoline. In May, 1949, Indianapolis, Ind., had a sewer explosion, tentatively laid to a short circuit in underground cables. The short circuit may have supplied the spark, but it doubtless was gas that exploded.

Perhaps the lack of adequate ventilation should be classified as a hazard, although the actual hazard is the gas that is not permitted to vent through the manhole tops in the streets. Most people think that the holes in manhole tops are provided for the purpose of lifting the lids. Re-surfacing of pavements has resulted in the sealing of many sewer vents with no thought of the ultimate danger involved. Snow also can effectively seal sewer vents, especially when compacted by traffic.

Mechanical ventilators have a place in sewage work only when the switches are sparkless, or remote from the source of gas, or both. All digester control and light switches were re-installed at the Findlay, Ohio, plant only after an operator was blown through the air by a control house explosion caused by turning off the lights. Methane gas and electricity do not mix safely.

Electrical work should be left to specialists with more certification than a receipt for union dues. Needless risks are taken by unthinking persons, as demonstrated in an Ohio plant several years ago. An elderly man was washing windows in an electric room, which was enclosed with a high mesh fence to prevent accidents, when his ladder toppled and he grabbed a buss bar—with fatal results. All janitor work within high voltage areas should be done by electricians.

Nothing is urgent enough to take "smartalec" risks to either personnel or equipment. Some characters delight in showing-off and are quite scornful of cautious persons. Others let a little authority go to their heads, and break all safety rules in the book. The trouble is that they frequently get away with unsanctioned behavior—until the law of averages catches up with them or their victims. No one is more contrite than the instigator of injury to another.

The walkways about a sewage treatment plant may be all that one could expect for completeness and safety, but they can still be dangerous. A case in point is the incident where a steel window sash swung out over a walkway. An operator, intent upon his inspection of a tank, collided with the outswung sash and toppled into the tank when thrown off balance. He could not swim, but managed to climb out of the sewage with help nearby. This might have been fatal in a one-man plant. Although plants designed for a single operator must include safety measures which might not be required in a fully staffed plant, the reviewing of sewage treatment works plans for approval of design seems to ignore personnel safety completely.

Wooden walkways should never be condoned from a safety standpoint. Concrete walkways are safe only when well drained to prevent frost damage and slipping. Railings are necessary. In many plants the concrete walkways have disintegrated until the reenforcing steel is exposed. The strength of such a structure is doubtful and this is an item where neglect becomes a hazard.

Inadequate illumination has been observed where the stair pitch is not uniform. This is re-doubling the bid for accidents. Standard stair treads are as important to the sewage plant operator as far as accident prevention is concerned.

If sewage and waste treatment plants were designed with safety as a major factor there would be fewer deep subterranean structures. In many old plants, and perhaps in newer designs, the location of equipment below grade is unnecessary and unwarranted. The machinery is vulnerable to flood damage, artificial light is required, operators must climb stairs or ladders, ventilation is mandatory, the gas hazard is increased, explosion damage may be greater, excavation and watertight walls add to the plant cost, and a costly overhead crane should be provided to handle heavy units safely. One wonders whether the extremely deep pits in some plants are the result of terrain, gradient, or some unusual condition; or whether they are the uncorrected first idea of the designer.

The energy cost to light underground areas is negligible, but experience has shown that sub-grade lighting circuits are costly to maintain and are frequently neglected. Thus, the men must resort to extension cords, which, in the condition that extension cords are usually found, add to discomfort and hazard potentials.

In accident prevention no one can anticipate those fellows who use windows instead of doors and who run hurdle races over aeration tank railings. Age alone will slow them down —if they live that long.

Mechanical devices in themselves do not seem to have caused as many accidents as an inept approach to repairing them. Mechanization in sewage work is decreasing the need for manual labor—and with better results. The purpose is not to save work for the incumbent operator, but to eliminate his helper and decrease costs.

Pathological hazards in sewage work can be mitigated by following the slogan, "Wash! Wash! Wash!" Careless persons are a danger to themselves, their families, and everyone they contact. On admission of the first poliomyelitis victim to a municipal hospital the sewage works operator requested that, as a precautionary measure, no wastes be discharged to the sewer system. The service director agreed that this was wise, but postponed issuing the order because the hospital sewer was then in process of cleaning and if the sewer gang heard of the polio they might not finish the job. Few sewer workers take enough precautions, and washing facilities are too seldom available. The very provision of washing facilities is a strong incentive toward personal cleanliness and they are used almost universally in treatment plants. Equal advantages should be provided for all sewer and sewage workers, including plenty of hot water and soap.

Superficial cuts must not be neglected. Our first state compensation claim arose from an operator's dislike of tincture of iodine, resulting in an ugly infection and threatened loss of a finger.

How operators have survived some accidents is anyone's guess. In one plant a relief operator was overcome by sludge fumes while transferring primary sludge to the hopper (below grade) before pumping to the digester. Luckily, he retained consciousness long enough to shut off the sludge valve, thus escaping drowning in raw sludge. An exhaust hood was installed after the incident had happened. The operator of this plant has long wanted direct pump suction lines to the tank.

In another plant a search for a gas leak disclosed that a water leg in the gas system had become dry and had been stuffed with rags to stop the gas. Here a need for education was evident, because the gas "leak" had been discovered in the **U**-shaped pipe arrangement but no curiosity had been aroused concerning the reason for such a pipe arrangement in a room containing motors, lights, and boilers and no report had been made on the incident.

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DISCUSSION

By Otto C. Haier

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The statement, "Accidents don't just happen," is universally true, regardless of the type of work done or the industry involved. It is certainly believed in the Standard Oil Company (Ohio). Although the disposal of refinery wastes is somewhat different from sewage disposal, the factors involved in accident prevention are very much the same.

Of course, the greatest hazard in the disposal of refinery wastes is that of fires, for the manufacturing process begins with a flammable liquid—crude oil—and ends with salable products of the order of butane, propane, naphtha, gasoline, lubricating oils, etc., many of which are far more dangerous than crude oil. Oil refineries, too, have workers with unpredictable actions and reactions, as well as stairways, walkways, electrical equipment, supervision, design, and machinery.

Mr. Barton has proved beyond a doubt that accidents don't just happen. He has pointed out many causes of accidents and, in addition, has presented a number of excellent ideas for their prevention.

His plea for the elimination of hazards in the design stage, by means of consultations between design engineers and operators of treatment plants, is laudable. The Standard Oil Company (Ohio), uses this method frequently. This is especially true in cases where new units are added to refineries or major changes are made. Numerous coordination meetings are held with responsible individuals from the operating units, the safety department and committee, and the engineering department. These meetings serve to resolve differences of opinion on all phases of the design, including safety and fire fighting facilities.

Mention has also been made of the value of periodic inspection of facilities to find hazards, existing or potential. This, too, is an excellent idea, found useful and necessary in industry. In the Manufacturing Department of Standard Oil Company (Ohio) there are numerous inspections. Each of the refineries has an inspection group within the engineering department. Briefly, the functions of these groups are to make periodic, thorough inspections of vessels, towers, piping, etc., determining metal thickness, extent of corrosion, and other conditions relating to the safe and continued operation and use of these facilities. When it is recognized that in the processing of petroleum, liquids, and gases are sometimes under great pressure and at high temperatures, one can see the necessity for making such periodic inspections. Line supervisors are also expected to be constantly on the alert for unsafe conditions and to take the necessary steps to correct them. Safety engineers are also employed in most locations. These men, too, are constantly on the lookout for hazards, potential or existing. In addition, they consult with the line supervisors, helping to devise safer ways and means, and new and better approaches to the worker and supervisor education problem.

A Safety and Fire Protection Committee (composed of home office representatives of the Engineering Department, Refining Control Division, and Industrial Relations Division of the Manufacturing Department) makes annual inspections of operating and laboratory facilities. This group seeks to determine the adequacy of safety and fire fighting facilities and to make recommendations for improvements to the vice president. Such groups and committees as just described may not be feasible for municipally operated treatment plants. However, many communities have safety directors who, in conjunction with the chief operator, engineer, and technical supervisor of sewers and treatment plants, could make periodic inspections of facilities.

Perhaps the most noteworthy statement in Mr. Barton's paper is that "Educational training along specific operation lines will do more to prevent accidents causing damage or injury than will all the codes, ordinances, and safety inspection regulations that could be drawn. . . ." That statement is one of many indications of the paper's true theme, which patently is "People need safety education."

The success of accident prevention endeavors, the same as other endeavors, whether economic, political, or social, depends on adequate education and enlightenment of people. Such education must stress the necessity and value of designing for safety, constructing for safety, maintaining for safety, and using things safely. Such education is a continuous process throughout everyone's life. It should not begin at the time a man is injured at work. It should not begin after a man starts to work as a designer. It must begin in elementary school or before, and be continuous from that point.

As a child develops, his adult habits and attitudes are formed. This, then, is the time to teach how to think, the time to develop the "questioning attitude," an important part of which is safety consciousness. Children must be taught how to live and act safely. This need not be done to the point of frustration or overcautiousness in the matter of playing, or adventure, or just plain living. However, a wholesome respect for all safety factors must be taught and the teaching must be continuous.

The idea of working and living safely must also be promulgated in the high schools and vocational schools, where the students are our eventual employees. If the causes of accidents—particularly those relating to poor design, or improperly guarded or constructed stairways, walkways, mechanical devices, and electrical devices—could somehow find their way to engineering colleges to be taught to future engineers, safer designs would result.

Training along specific operational lines, as Mr. Barton suggests, cannot be given in schools. It must be given on the job, whether in the sewage treatment plant or in the petroleum refinery. Without it, all previous education may be valueless.

LIMING OF SLUDGE DIGESTERS OR DIGESTION COMPARTMENTS *

By J. Henry L. Giles

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Arguments have been presented in the literature against any liming of digesters. Therefore, the following points for and against liming, as observed in the combined experience of several Connecticut sewage treatment plant operators, both at state institu-

* Presented at 1949 Spring Meeting, New England Sewage Works Association; Bristol, Conn.; May 25, 1949.

tions and in municipalities, may be of interest. Also included are some supplemental data resulting from recommendations by the writer as a supervising sanitary engineer with the State Health Department.

For the purpose of this discussion, items are listed that are possible of easy observation by the less experienced operator in determining whether or not digestion is progressing satisfactorily. Such a listing, for purposes of identifying good sludge as opposed to poorly digested sludge, might include the following:

Characteristic	Good Sludge	Poorly Digested Sludge
Color	Black	Brown or gray
Odor	Tarry	Septic
Appearance	Homogeneous	Individual particles
Compaction	Excellent	Very poor
Supernatant	Clear	Very turbid
Gasification	Strong	Weak
Drying time	10 days or less	3 weeks or more
pH	6.5 to 7.0	Less than 6.0
Alkalinity	Above 1,800 p.p.m.	Below 1,000 p.p.m.

Procedure for Adding Lime

Many small plants have no special facilities for adding lime to a digester or to the digestion compartment of an Imhoff or septic tank. Nevertheless, depending on the type of unit involved, at least one of several methods can be employed or adopted when liming is indicated. Among the less complicated means that have been found successful are: (1) sprinkling dry lime lightly over the scum and mixing it in by hosing or plunging; (2) sprinkling dry lime lightly into the flow of raw sludge in a manhole on the way to the digester; (3) adding milk of lime, made by mixing hydrated lime with water, either through a submerged pipe (if continually moved), through the suction of a sludge pump, or by spreading over the scum in the gas vents.

Observations on Liming Practice

When starting up a heated digester it should be considered the same as an unheated tank. During this initial period it has been found advantageous at Connecticut sewage treatment plants to maintain the pH of the entire contents of the tank at 6.8 to 7.0 by small daily additions of lime for the first month, or until digestion is well started with the production of methane gas. Before adding any raw solids to the tank, its liquid contents should be raised to a minimum temperature of 75° or 80° F. After that, the heated digester will operate without liming if the capacity is large enough for the load and the temperature is maintained between 90° and 100° F.

When starting up an unheated separate sludge digestion tank or an Imhoff tank it has been found in Connecticut that regular liming of the digester in small amounts (approximately 50 lb. per 1,000 population per week) will avoid the period of septic, odorous, acid digestion frequently noted during the first 3 months of starting up any digester. For unheated digesters and Imhoff tank digestion compartments having a capacity of 2 cu. ft. or less per capita, regular daily to semi-weekly lime additions have avoided the conditions of having all the solids float, a severe acid reaction, and very poor digestion.

At one Connecticut institution the population has increased from about 1,000 to nearly 4,000 in the past 20 years. The settling and digestion tanks have remained the same, except for the installation of a sludge pump and utilization of the entire contents of the digester. Years ago, with about 2 cu. ft. capacity per capita, very little liming was practiced and trouble was

experienced frequently with heavy scum and raw sewage solids because the operator was repeatedly drawing off too much of the seed sludge and too much sewage was added from the settling tanks. Now, with less than 1 cu. ft. per capita digester capacity, and the use of about 100 lb. of lime weekly in two batches, the tank is kept in reasonably good operation despite the fact that complete digestion is not obtained.

At another institution of over 3,000 persons a shallow digester (one of the first two built in Connecticut) had been in operation a year when the writer first inspected it. It was found to be very septic. No digestion had started, apparently because of daily additions of raw sludge and excessive drawing of sewage to the digester. By regular weekly additions of lime this septic condition was corrected and reasonable digestion was obtained during 15 years, until the tank became overloaded with solids because of its long compartment design, which did not facilitate sludge removal. During the past year, with the discontinuance of liming in anticipation of a new digester, excessive septic scum has built up again.

At another state institution of 200 persons, with the same general design, but with easier access to the scum for plunging regularly, 10 to 15 lb. of lime added weekly have kept the tank in good operating condition for 17 years. Because of operator neglect, however, lack of liming and plunging occasionally gave an acid scum, although the sludge was not affected because the condition was corrected in time.

Without liming, all Imhoff tanks in the state at one time or another have developed 2 to 18 ft. of scum; a pH below 6.0 (even as low as 5.0); and poor, pasty, slow drying sludge. By regular liming and wetting down of the scum by hosing and/or plunging, they have been brought back to good operation, as judged by blacker sludge, a pH of 6.4 to 7.0, and stronger ebullition of gases, which has a tendency to keep down scum accumulations.

There have been examples of heated digesters with 1 cu. ft. per capita capacity being started without liming or heat and even months later, when heat was up, failing to give adequate digestion, with a sludge pH below 6.0 and the development of 4 to 8 ft. of thick raw scum. Regular liming, coupled with various methods of scum plunging, has greatly improved operations and provided a satisfactorily digested sludge and controlled scum depths.

When Liming Is Not Indicated

As previously mentioned, a properly operating digester of adequate capacity—for a heated tank a minimum of 2.0 cu. ft. per capita for average domestic sewage, more when industrial wastes are present, and not less than 2.5 cu. ft. per capita where secondary sludge is pumped to the digester; for an unheated tank 3.5 cu. ft. or more per capita—does not usually need lime. Sufficient capacity, continuous heat, monthly drawings of digested sludge, daily drawing of sludge from settling tanks without excessive drawing of sewage, and control of scum by breaking up or removal where necessary, appear to be governing conditions which permit good digester operation without lime.

Poor liming practices—adding a bag full (50 lb.) in spot dosages, adding several hundred pounds at a time at monthly intervals, or excessive liming—have all been experienced at one plant or another and definitely are not recommended.

At one small city sewage treatment plant with 3 heated digesters, heavy wool fibers bothered plant operation by causing mostly scum and very little sludge. Liming was tried daily for two weeks and all scum finally settled out. However, the pH was over 8.0

and all digestion action stopped. Raw sludge was added and the tank contents were mixed by circulating from bottom to top until digestion started again, with a pH of about 6.8. The resulting sludge after 3 months time was very odorous and poorly digested. It was concluded that excessive liming to settle scum was of little if any advantage. Liming was never tried again at that plant because of the excessive cost and because the operator found that by heating the digesters to 90° F. and permitting uninterrupted digestion, the entire contents of a tank could be dumped by the aid of hosing, without nuisance, even though all solids formed as a floating scum under the digestion tank covers. This is admittedly a rather unusual operating experience, which was no doubt due to the heavy preponderance of industrial wastes.

Two shallow unheated digesters were being limed fairly regularly when it was found that sludge could not be drawn from the regular sludge draw-off pipes. When the tanks were dewatered big lumps of lime were found mixed with sand in the sludge hoppers. Installation of a grit chamber to remove sand, and controlled liming, have resulted in satisfactory operation for several years.

At one institution of 500 persons, trouble was experienced in getting rid of the accumulation of raw solids in the inlet end of the flowing-through compartment of an Imhoff tank. Repeated drawings of sludge did not help the condition, but only depleted the valuable seed sludge. Finally, the institutional engineer drew the tank down completely, and by hosing and dilution with sewage flow was able to break up a heavy bank of lime mixed with sand which had formed in the inlet hopper and which kept raw sludge from settling out. The tank was started up again without liming, but was seeded from an adjoining tank. A very septic condition developed and continued for 6 months. Very light, carefully distributed weekly additions of lime in 25-lb. batches have brought this tank back to good operation with very little scum, a pH of 6.8, and an easy drawing, good drying sludge. The sand now is removed at the screen chamber, where a baffle has been constructed to settle it.

Conclusions

In conclusion, representatives of the Connecticut State Health Department, in collaboration with many sewage treatment plant operators in the state, believe there is a place for proper liming of heated or unheated digesters and of digestion compartments of Imhoff tanks. It is agreed, however, that liming should be carefully controlled, with the chemical added in small quantities daily to twice weekly and mixed with the flow of raw sludge whenever possible. It should not be added in large amounts, infrequently, or dumped in one place in a tank.

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DISPOSAL OF CONDENSED MILK BY DIGESTION

By David P. Backmeyer

Superintendent, Water and Sewage Treatment Utilities, Marion, Ind.

An excellent example of how cooperation between the municipal sewage treatment plant and industry can help to sidestep trouble for the operator is contained in the recent handling of a heavy "slug" of otherwise troublesome produce waste by the Marion, Ind., sewage treatment plant. The circumstances causing the incident were somewhat unusual, and called for an unusual although simple solution.

On August 5, 1949, a local produce plant was involved in a labor dispute and the workers went on strike. On hand was 11,000 gal. of condensed milk, which the strikers would not allow out of the plant. The milk could not be held indefinitely, and if dumped into the sewers it would seriously upset the activated sludge treatment plant. Obviously, some means of disposal was needed.

With a total dry solids content of 24.5 per cent and a volatile solids content of 94.4 per cent, the total volatile solids involved in the 11,000 gal. of

TABLE I.—Gas Production Resulting from Addition of Condensed Milk to Marion, Ind., Digesters

Date (1949)	Condensed Milk Added (gal.)	Gas Produced (cu. ft.)			CO_2 Content (%)
		Total	Normal	From Milk Load	
Aug. 3	—	74,900	74,900	—	35.6
4	—	74,621	74,621	—	36.0
5	11,000[1]	74,234	74,234	—	36.6
6		126,875	69,500[2]	57,375	36.2
7[3]	—	141,630[4]	59,500[2]	82,130	—
8	—	87,000	68,000[2]	19,000	34.4
9	—	87,000	69,500[2]	17,500	34.6
10	—	84,000	71,500[2]	12,500	33.8
11	—	76,000	74,000[2]	2,000	34.2

[1] Approx. 20,000 lb. volatile solids.
[2] Estimated from past experience.
[3] Sunday.
[4] Partly estimated by measuring cover drop on release from dome.

condensed milk amounted to about 20,000 lb. This was not considered to be too heavy an extra loading for the plant digesters, as almost all of it would be quickly removed in the form of gas or supernatant.

Consequently, the entire volume of condensed milk was hauled to the treatment plant in the tank trucks normally used for hauling liquid sludge. At the plant it was dumped into the ground-garbage well for pumping to the digesters. Hauling and loading to the digesters was started on August 5 and completed on August 6. Digester temperature was 99° F. throughout the entire operation.

The resulting gas production was rapid and spectacular. On August 6 it was nearly double the normal daily volume, and on August 7 was so great that the plant gas meters were inadequate to handle it. Part of the volume (Table I) was estimated by measuring the drop of the floating cover as the gas was released directly from the cover dome. The previous gas production record for the plant (110,000 cu. ft. per day) was set during the summer of 1948, when cheese whey was being handled by the same method (see THIS JOURNAL, **20**, 6, 1115; Nov., 1948).

No increase in CO_2 content of the gas was apparent. In fact, no noticeable ill effects of any kind have resulted from the unusually heavy shock load, the digestion system seeming to have taken the material in stride.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"When your work speaks for itself, don't interrupt."

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage Works Associations, Room 325, Illinois Bldg., Champaign, Ill.

Seventeenth Annual Report of the Division of Sewage Disposal, Toledo, Ohio, for 1948 *

BY A. H. NILES, *Engineer-Superintendent*

The sharp increase in sewage flow experienced during the first half of 1947 continued throughout 1948, indicating that the flow represents firm growth, both industrial and domestic.

Gas Engines

The gas engine driven pump, fueled with digester gas averaged 31.8 m.g.d., or 363 gal. per cu. ft. of gas for the year. This is the greatest amount pumped and at the greatest efficiency in the 12 complete years of operation of the engine. This speaks well for the quality of maintenance not only of the gas engine but also of the 36-m.g.d. rated capacity pump, which is over 26 years old. The 2 gas engines installed late in 1936 at an original cost of $41,075 have now saved a total of $170,909.51 in the cost of electric current used at Bay View Park.

Tol-E-Gro

The tonnage available for the spring of 1948 was the lowest in several years, due to the painting of the superstruc-

* For last previous extract see THIS JOURNAL, 20, 6, 1114 (Nov., 1948).

TABLE I.—Summary of Operation of the Toledo (Ohio) Sewage Treatment Plant for 1948

Item	Average
Rainfall (in.)	33.21
Design flow (m.g.d.):	
Mean D.W.F.	80.0
Max. D.W.F.	140.0
Raw sewage flow (m.g.d.)	44.8
Screenings (cu. yd. per month)	177
Grit removed (cu. yd. per month)	64
Suspended solids (p.p.m.):	
Raw Sewage	194
Plant effluent	93
Per cent removal	52.0
B.O.D. (p.p.m.):	
Raw sewage	189
Plant effluent	124
Per cent removal	34.7
Per cent volatile solids	
Raw sewage	65.6
Digested sludge	42.2
Digested sludge (cu. yd.):	
To marsh	25,470
To drying beds	10,340
Tons dry sludge pulverized for fertilizer	1,074
Tons fertilizer sold	824
Total sales ($)	10,181
Bay View pumping station costs ($ per m.g.):	
Purchased power	0.27
Supplies	0.49
Supervisions and labor	3.73
Total	4.49
Sewage works cost ($ per m.g.):	
Power	0.008
Supplies	2.24
Supervision and labor	6.63
Total	8.83
Gas engine economy ($):	
Pumping cost if power purchased	24,747.41
Actual pumping cost	6,217.53
Gas engine saving	18,529.88

ture of the sludge drying beds during the summer of 1947. Partly as a result of the decreased amount available and partly due to the absence of a raise in price for several years, the price schedule of Tol-E-Gro was increased on Jan. 1, 1948. Without this price increase profit would have made a very bad showing in 1948, as processing costs have risen steadily.

Revenue

Sewer rental revenues continue to increase, but not as fast as expenses. The total for 1948 amounted to $276,675 as compared to $259,795 in 1947, and about $241,000 in 1946. Sales of Tol-E-Gro and miscellaneous revenue bring the total receipts to about $294,085 for 1948, as compared to total of $276,787 for 1947, and $264,257 for 1946. This money is not all available to this Division, however, as some other accounts have been financed from the "Sewerage Fund." When secondary treatment financing is seriously studied this matter must be considered also.

Secondary Treatment

Detailed plans and specifications have been completed by a consulting engineer for the activated sludge type of secondary treatment. Plans and specifications have been approved by the Ohio State Department of Health and the Federal Works Agency. This improvement is now in such a shape that contracts for the various parts of the work could be immediately let after the necessary advertising for bids. Financing is the main delay.

A summary of plant operation data is given in Table I.

Seventeenth Annual Operation Report of the DeKalb (Ill.) Sanitary District Sewage Treatment Plant, for the Year 1948 *

By Donald E. Henn, *Manager*

The treatment plant was in continuous operation during the year, and no sewage was by-passed except storm flow at the filters when the flow was above the capacity of that unit. All flow received at least primary treatment.

* For last previous extract see This Journal, 20, 5, 915 (Sept., 1948).

Primary Settling Tank

This unit, equipped with a "Dorreo" traction clarifier, provides a 2-hr. detention period with a 1.8-m.g.d. rate of flow. The sliding electrical contacts require regular attention, as the wear produces shorts in the system or improper contact. Other than the minor electrical troubles the mechanism, which has completed 19 years of continuous operation, shows no signs of appreciable wear.

Sprinkling Filter

The two 6-ft. deep units, totalling 0.9 acre in area, are designed to operate at 1.8 m.g.d. per acre with overloads up to 2.25 m.g.d. per acre. The beds operated efficiently and without serious difficulty throughout the year. No evidence of rock spalling in the beds or clogging of under-drains developed, and no ponding of importance was experienced. The beds unloaded in May and to a much lesser extent in the fall. Due to high flows and strong sewage dosed to them during the canning season, considerable solids were unloaded throughout the summer months.

This unit removed an average of 70 per cent of the B.O.D. of the primary tank effluent and 35.8 per cent of the total B.O.D. of the raw sewage as determined by tests.

Sludge Storage Tanks

The two sludge storage tanks, providing a total of 23,000 cu. ft. capacity, received sludge from the digester during the winter and at other times when no drying beds were available. They were also used as sludge conditioning tanks when thin or partially-digested sludge had to be drawn from the digester. In July, August, and September (during the canning season) these tanks were used as secondary digesters. Sludge was drawn to them during the winter as it accumulated in the digester. The removal of supernatant liquor during February made sure that ample room would be available for all sludge drawn from the digester until late March.

On April 26 the summer business of pumping these tanks out was started. They were empty in June, were used as secondary digesters through July, August, and September, and were very nearly full late in September. They were again pumped out during October and November and were empty on November 29. At year's end very little sludge had been drawn to them, leaving ample capacity available to carry over until spring.

Canning Wastes

The canning plant operated on 66 days between June 20 and September 24. Peas were canned on 30 days; corn and/or lima beans on 36 days. An early spring and ideal growing season produced the best crop year in the history of this canning plant. On June 26 the DeKalb plant packed more cases of peas than any plant of the California Packing Corporation had ever packed in one day, breaking not only

TABLE II.—Summary of 1948 Operating Data, DeKalb (Ill.) Sanitary District

Item	Average
Total rainfall (in.)	32.18
Tributary population	13,300
Sewage flow (m.g.d.):	
Av.	1.31
Max.	3.20
Min.	0.60
Suspended solids (p.p.m.):	
Raw	211
Settled	69
Filtered	64
Final	42
Per cent reduction	79
B.O.D. (p.p.m.):	
Raw	255
Settled	130
Filtered	39
Final	36
Per cent reduction	86.5
Digester gas produced (1,000 cu. ft. per day)	14.2
Power used (kw.-hr. per day)	77.7
Operating cost ($):	
Total	14,793
Per capita	1.10
Per m.g.	30.82

the record for this plant but also that of the corporation as well. In 1947 a very large pea crop was packed, but the corn and lima beans were below average. This year all crops were exceptional and the canning plant ran on almost 24-hr. schedule during the canning season. Though the number of cases packed was well above average, the crops were all good and needed little washing or extra processing. Thus, the total organic wastes produced were about average and no unusual load or problems were encountered at the treatment plant.

Plant Grounds

The asters and "glads" grown at the plant are constantly and quietly becoming better known, and more people each year drive to the plant to see and admire them. Many plants are given away each year to citizens of the District—this to further the ambition not only of beautifying the plant grounds, but also of helping add beauty to many gardens located in the district. The flower beds not only added greatly to the plant's attractiveness, but also furnished flowers for many bouquets given to visitors.

The more than 4 acres of lawn were kept mowed and trimmed and the road to and around the plant was kept well graded. Fourteen loads of cinders were hauled for the roads.

During the summer months a small greenhouse (15×17 ft.) was constructed. It is heated by hot water from the gas-fired boiler located in the office. Thus, the cost of operation should be almost nil.

Operating data for the plant are summarized in Table II.

Annual Operation Report of the Medina, Ohio, Sewage Treatment Plant for the Year 1948

By W. Eugene Schlechty, *Superintendent*

The plant, built in 1931, originally consisted of one bar screen and one grit chamber (both manually cleaned); two primary settling tanks with sludge collectors; twin dosing tanks to operate the standard trickling filter; a final settling tank; two sand filters; two grass filters; a floating-cover type, heated digester; four small, glass enclosed, sludge drying beds; a control building containing sludge pump and piping, gas equipment, etc.; and a building housing a garage and workshop on the first floor, with office and laboratory on the second floor.

Since that time the two sand filters and the two grass filters have been converted into sludge drying beds, and three additional sludge drying beds have been made. Also, a waste gas burner with regulator and flame trap was installed. A small tool shed was erected, as was a concrete-block building to house the chlorinating equipment. Chlorine is applied just ahead of the dosing tanks during the summer months only. The plant is overloaded and must be enlarged as soon as funds permit, the tributary population having increased sharply during the past few years.

Repairs and Improvements

During the year both primary settling tanks were pumped out for inspection. New support clamps were put on the sludge drawoff lines in both tanks. The chlorine building was wired for lights, and a flood light was placed over the dosing tanks. A new stone drive was constructed between the chlorine building and the plant drive.

In the three north sludge beds 750 ft. of 4-in. land tile was laid to replace the original ones, which had been broken when trucks hauled sand onto the beds. A heavy plank bridge was

built across the east creek to facilitate the handling of surplus dried sludge. Four sets of steps, including handrails, were replaced with new wooden ones. Window and door screens were fitted to the office and laboratory, the control building, and the chlorine building.

A P.F.T. flame-trap was purchased to replace the water-seal type in the control building, thus adding another safety factor to the gas equipment. An electrically operated water-still with low water cut-off was purchased to replace the old copper retort, which had given many years of service.

A drop manhole—approximately 25 ft. deep, 5-ft. inside bottom diameter, 4-ft. inside top diameter—and 132 ft. of triple strength vitrified 24-in. pipe were added to the existing by-pass line. Labor was recruited from the street, water works, and disposal plant departments.

Storm Water Survey

To aid in eliminating storm water flow from the already overloaded plant, a 5-month survey was conducted to determine the source of storm water entering the sanitary sewers. This was accomplished by dropping numbered rubber balls in all downspouts, catch basins, and other likely openings in the area having sanitary sewers. A total of 1,944 balls were dropped (some areas were covered twice). Of the 55 balls received at the disposal plant, 2 were from street catch basins and 1 from a catch basin behind a business block.

Recommendations

In addition to complete elimination of storm water from the sanitary sewers it is recommended that a sewer rental ordinance be enacted to put the plant on a paying basis. By this means financing can be considered for plant enlargement, for which definite plans should be made immediately.

Operating data for the plant are summarized in Table III.

TABLE III.—Summary of 1948 Operation Data at Medina, Ohio

Item	Average
Tributary population	6–7,000
Equivalent population (B.O.D.)	12,000
Sewage flow (m.g.d.):	
Av.	0.49
Max.	1.17
Min.	0.20
Suspended solids:	
Raw (p.p.m.)	263
Settled (p.p.m.)	138
Final (p.p.m.)	62
Reduction (%)	76.1
B.O.D.:	
Raw (p.p.m.)	567
Settled (p.p.m.)	473
Final (p.p.m.)	54
Reduction (%)	90.1
Digester operation:	
Average pH	7.4
Average temperature (° F.)	86
Digested sludge, dry solids (%)	5.7
Digested sludge, volatile solids (%)	48.2
Gas production (cu. ft. per day)	4,900
Operation cost ($):	
Total	10,185
Per m.g.	60.95

SLUDGE REMOVAL AT MEDINA, OHIO

By W. Eugene Schlechty

Superintendent, Sewage Treatment Plant, Medina, Ohio

The sewage treatment plant at Medina, Ohio, was put into service in the winter of 1931. It consisted of bar rack, grit chamber, 2 primary settling tanks, a dosing tank for the fixed-nozzle type trickling filter, secondary settling tank, single-stage digester, covered sludge beds, 2 sand filters, and 2 grass filters.

Originally the sludge drying area

consisted of 1,672 sq. ft. of glass-covered beds. Later, the sand filters, having an area of 11,760 sq. ft., were taken for sludge drying. In 1943, the 2 grass filters were converted to sludge drying beds, providing an additional 11,760 sq. ft., and in 1944 still another sludge drying area of 13,750 sq. ft. was added. The last addition was needed to handle sludge from the humus tank that could not be pumped satisfactorily to the digester.

The dried sludge is removed from the covered beds by an overhead carrier. Sludge on the open beds was removed by wheelbarrows until the spring of 1948, but in the 2-man plant this required hiring of 2 extra men during the summer months for sludge removal alone. The method proved not only expensive, but also tiring, as some of the sludge had to be wheeled for some distance.

Late in 1947 a small tractor with 10-in. wide treads was purchased. A hydraulic loader mounted on the front end was modified by a local machine shop into a true bucket with a hinged door in its forward end. The scoop, originally intended for loading such loose materials as snow and sand, holds 16 cu. ft. of dry sludge as shoveled in; if packed in, it holds 20 cu. ft.

The tractor is driven onto the beds and the sludge is shoveled into the bucket as shown in Figure 1. When full, the bucket is raised and the sludge taken to the dumping ground, from where the public is allowed to haul it away without charge. The bucket can be tripped at any height, thus enabling piling of the sludge to a height of 6 ft., or dumping directly into a truck for hauling. In fact, some haulers take advantage of the arrangement to have the loader dump directly into their trucks at the beds.

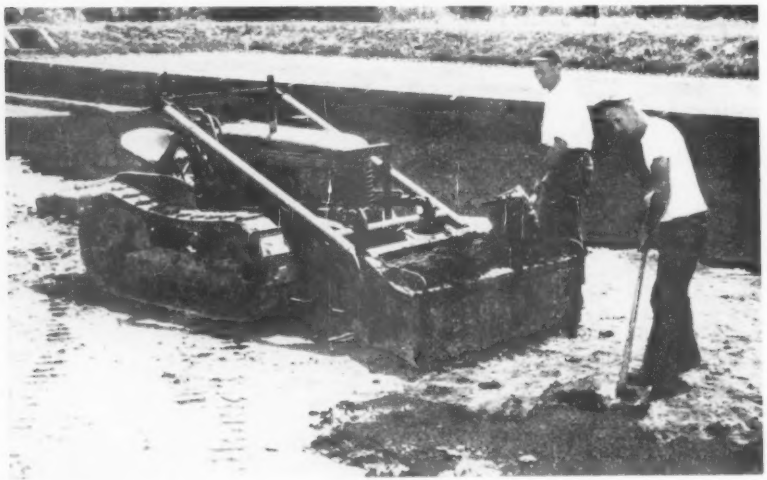

FIGURE 1.

The tractor and loader as described cost about $2,240 in 1947. Operating cost, not including depreciation or possible repairs, runs about $1.25 for 8 hr. Using the loader, only one extra man is required during the summer months and the sludge can be removed in about one-third the time formerly required with wheelbarrows. In 1948, approximately 10,000 cu. ft. of dry sludge were removed from the open

beds, representing 625 loader loads, or 3,333 wheelbarrow loads.

It was first thought that the tractor might tear up the beds, but the beds actually seem to benefit, as the sand is kept loose. The underdrains are deep enough so that they have not been damaged. After the sludge is removed from the beds, they are partly leveled by dragging the bucket in reverse, then floated by hand. This is the second year of sludge removal by this method, which has so far proven satisfactory.

Many other uses have been found for the tractor around the plant. The bucket can be removed and other equipment fastened in its place, so that the rig can be used as a bulldozer, snowplow, grader, etc. To offset the bucket loads, of course, the rig must be counterweighted.

PREVENTIVE MAINTENANCE AT TOLEDO, OHIO *

By Elmer Pollex

Chief Operator, Sewage Treatment Plant, Toledo, Ohio

One of the first things in preventive maintenance is to be on the lookout for possible trouble at all times. All personnel at the Toledo, Ohio, sewage treatment plant work along the same lines as would a police department; that is, in making his regular rounds of duty each man is to watch and listen for any strange noise or action of all equipment. If he is suspicious of anything he finds, he is to investigate and report it to his supervisor. The supervisor then checks to determine what the trouble may be. Often there is no trouble, but it is preferred to have a false alarm rather than the real thing. A record is kept of all ailments, and they get special attention until known to be all right. When any peculiar sound is found in a piece of equipment there is a reason for it, just as there is a reason for the blowing of an electric fuse.

Detritors

Detritors, bar screens, organic pumps, and ejectors are inspected each 6 weeks and drained once a year for thorough inspection, any necessary work being performed at that time. The pintle chain for operating the bar screen raking mechanism is turned over each year for longer life. The sprockets were turned over in 1940, and in 1948 the first set of new sprockets was installed on the two bar screens since the starting of the plant. The life of the pintle chain is about 6 years.

The air compressor is checked every 3 months for the output of air. It is run to the point of making the pop valve operate so that the safety feature is assured. In 1940 a new set of rings and valves was installed in the compressor, which is still putting out the required amount of air.

Clarifiers

Each of the eight 90-ft. square traction clarifiers is drained and inspected once a year, any necessary repairs being made at that time. In 1948 installation of the first replacement set of carrying plates was started. These plates carry the weight of the mechanism as it rolls across the central supporting pier. To date five units have been completed; the work on the other three is expected to be done this year. The carrying rollers and guide rollers are calipered at each inspection. The present carrying rollers are made of

* Presented at 23rd Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cleveland, Ohio; June 22–24, 1949.

alloy steel No. TA 135 and have a 16¼-in. diameter. The original rollers were of chilled cast iron and had a 16-in. diameter. It is found that after installing a new set of carrying rollers and re-setting the scraper blades, the latter wear down in direct ratio with the carrying rollers. The extra ¼ in. on the diameter of the rollers extends their life to about 8 years, as compared to about 5 years if they were of only 16-in. original diameter. They are allowed to wear down to about 15½ in. before replacing them.

The traction wheels were remodeled in somewhat the same manner. The original 12-in. tires of silicon steel only lasted about 3 years. Therefore, the cast iron hubs were turned down to 9¼-in. diameter, and 50- to 60-point carbon steel ring forgings were made to machine to 12¼-in. O.D. by 9¼-in. I.D. These tires were then shrunk on the hubs. It is felt that the extra ¼ in. of wear helps replace the wear of the rails. The life of these tires is 5 to 6 years, and they are worn down to 11¾-in. diameter before being cut off for replacement.

Digesters

In the eight 85-ft. diameter fixed-cover digesters, all thrust stirring mechanism bearings are cleaned and inspected every 6 months. If any bearing or retainer shows signs of wear, it is replaced. In the slow speed bearings (running only 1/44 r.p.m.) the pressure is so great that it is not worth taking any chances. Regardless of how closely these bearings are watched, there are still failures, such as a broken ball. The average life of these bearings is about 7 to 8 years.

The worm and worm gears are washed and cleaned once a year and inspected for wear, although they are watched daily by the operator and oiler for signs of wear. After 17 years of service all the worm gears are in very good shape, the only mishap during that period having occurred in June, 1939, when grit in the grease badly scored one worm gear and worm. The worm gear was turned over and the worm replaced. The average life of a worm is 10 years. A special emery wheel that fits the teeth of the worm gear is used about every third year to polish up all teeth. This avoids much scoring and makes them like new.

Three digesters have been emptied to date for interior inspection—one in September, 1940, one in November, 1941, and one in November, 1947. The same condition was found in all three. All heating coils and hangers were as good as new, the small amount of scale being chipped off before the digesters were restored to service. However, the one opened in 1947 showed a certain amount of pitting on the arms of the sludge scraping mechanism. The small channels and latticed girders used to brace the four main arms of the digester were pitted considerably more than the main arms themselves. The rust and scale was entirely removed by chipping and wire brushing. On part of the arms, one coat of asphalt paint was applied; on the other part, two coats. Although the steel did show some deterioration, it would be a very long time at the rate indicated before any structural failure would occur. It was originally intended to empty one digester each year for inspection, but they were found in such good shape that a few years were missed. Another tank will be drained this year if conditions permit.

All gas line joints and valves are inspected for leaks once every 3 months with soap suds—each time by a different man, so that if one man misses a small leak another will find it. The gas-fired hot water boilers for heating the digesters are used only 4 months and then are thoroughly cleaned and blown out.

The three 10-in. by 10-in. digested-sludge pumps are completely overhauled once every 2 years. The only appreciable wear has been in the

bronze ball-check seats, the life of which is about 4 years. New sleeves were put on the pistons for the first time in 1945, making the life of the sleeves 13 years. It is fortunate, however, that the sleeves are nothing but ordinary steel tubing, as the manufacturer no longer makes this type of pump.

Electric Motors

All electric motors are blown out once a year with air. Every 2 years they are torn down, cleaned with carbon tetrachloride, and revarnished with insulating varnish. In the 17-yr. service of eight 3-h.p., eight 5-h.p., and four 2-hp. motors (all 440 volts, 3 phase, 60 cycle, running 24 hr. per day) there has not been a single motor failure. It was felt, however, that this could not go on forever, so a spare was purchased in the 3-h.p. size and another in the 5-h.p. To date these have not had to be used. Among the other motors of various types that run only part of the time only 4 have burned out or shorted out. With a total of 84 motors ranging in size from $\frac{1}{30}$ h.p. to 50 h.p., it is felt that this is a very good record.

All electric starting boxes and switches are checked and cleaned every 6 months. In addition to the office record, a card is kept in each box showing when it was cleaned, what condition it was in, and by whom it was checked.

Lubrication

A total of 832 points of lubrication are greased or checked daily. All oil and grease is changed once a year. To date there has not been a single failure of any piece of equipment, bearing, or bushing because of the lack of grease or oil. A complete record of all inspections and work done, including the name of the person or persons making the inspection or overhaul, is kept in a file in the office. If it is felt that a certain item needs attention at a certain time, a note is made of it on a yearly desk calendar and when that time comes it is inspected again.

Chlorination

All chlorine equipment is completely overhauled and inspected once a year. This takes one man about 30 days, as every valve and line is taken apart for cleaning, inspection, and installation of new gaskets. By doing this it is found that all chlorine machines can be operated during the summer (using about 135 tons of chlorine) with very little trouble. At times, all of the 10,000-lb. per day capacity installed is in use.

General

One failure it is desirable to prevent, and of which there is no warning, is the shorting out of underground lead cables. In the last 6 months, two underground 440-v. cables have shorted out. One, under the concrete floor of a 140-ft. long clarifier, could be pulled out and replaced. The other, 85 ft. long and also under the concrete floor of a tank, could not be pulled out. To restore electric service to the detritor required abandonment of the old conduit and installation of a new conduit and wire, as well as a lot of concrete cutting.

A wooden frame with glass cover is made for instructions of operation, oiling, etc., of each item of machinery and hung near the piece of equipment so it can be seen and read by all. This is felt to be much better than having the instructions in an office file where they may be seen only by the one or two who happen to stumble on them.

At present all equipment is in very good shape, there being nothing that is in need of serious repairs. All the maintenance work is done with plant personnel except for heavy machine shop work, which is sent out because of the lack of lathes and shapers.

FLOW MEASUREMENTS *

By Walter N. Stancati

Foxboro Meter Co., Pittsburgh, Pa.

The subject of this paper is confined to flow measurements by means of weirs and flumes, which are used for measurement of flow in the smallest sewage and industrial waste disposal plants as well as the largest. Both sewage and industrial waste often flows in open channels under low head and over wide ranges of flow, the weir or flume often being the only satisfactory means of measurement.

Contrary to orifice plate calculation practice, flow formulas for weirs or flumes are based on the fact that the velocity of the liquid at various points in the jet through the weir notch varies and is proportional to the square root of the depth of the stream at each point, the depth being the effective head causing flow at the point. Actually, this head cannot be measured at the weir, because the stream level falls considerably below upstream channel gradient as the water accelerates in approaching the notch. Consequently, all practical weir formulas express flow as a function of head measured some distance upstream, where the liquid surface is quiet and where the stream level gradient is still normal. Also, the flow lines through the notch are not at right angles to the plane of the weir, so it is not practical to multiply areas in the plane of the weir by the average stream velocity to get the flow. Therefore, formulas with constants derived theoretically from over-simplified hydro-dynamic considerations will not give correct flow values. As a result of numerous experiments, coefficients corrected for the effects mentioned above have been obtained. Flows computed with the aid of these coefficients are accurate, well within commercial limits. It is highly important, therefore, for the engineer or sewage works superintendent to use a weir or flume having firmly established flow coefficients, obtained from actual experiment.

All weirs in general use are "sharp crested" types using notches of regular shape. Although calibration curves can be established for any weir through experimental data, the types in general use are: (1) the triangular, or V-notch weir; (2) the rectangular weir with end contractions; (3) the Cippoletti weir, a modified rectangular type; and (4) the Sutro weir.

The Parshall flume is the flume in widest use in sewage flow measurement, although there are other types designed for special applications. It is not within the province of this paper to discuss these special flumes. There are also special flow nozzles, such as the Kennison nozzle and the parabolic flow nozzle.

The triangular, or V-notch weir is cut from the weir plate at an accurate angle of either 60° or 90°, meeting in a point. It is especially well adapted for use where a wide range of flows is to be measured, because of the comparatively large change in heads at low flows. Also, it is less affected by high velocities of approach than are rectangular weirs. This type of weir may, however, require too great a depth of channel or too great a variation of head for some applications. The flow equation is

$$Q = 1.4076\ H^{5/2}$$

for a 60° V-notch weir, and

$$Q = 2.4381\ H^{5/2}$$

for a 90° V-notch weir. In these equa-

* Presented at First Annual Meeting, West Virginia Sewage and Industrial Wastes Association; Bluefield, W. Va.; Oct. 1–2, 1947.

tions Q is the flow, in c.f.s., and H is the head on the weir, in feet.

The rectangular weir is generally used where flows are too great to measure with V-notch types. It should be constructed with end contractions; that is, a rectangular notch should be cut from the weir plate so that the horizontal distance between the vertical section of the weir and the end is greater than twice the maximum head of flow over the weir. Rectangular weirs are seldom used where the notch length is less than 1 ft. The flow equation for rectangular weirs is

$$Q = 3.33\ (L - 0.2\ H)\ H^{3/2}$$

in which L is the overflow length of the weir.

The Cippoletti, or trapezoidal weir, is cut for a level crest, but having the sides of the notch inclined outward from the vertical at slopes of 1 unit horizontal to 4 units vertical. It is also designed for end contractions, as is the rectangular weir, and is generally not used where the notch is less than 1 ft. in length. The coefficients for this weir have not been checked too thoroughly, and it is not recommended where a high degree of accuracy is required. The flow equation is

$$Q = 3.367\ LH^{3/2}$$

The Sutro weir, which has a special form of closed notch, is not generally used. The primary purpose in developing this type was to obtain a linear relation of flow to head to make instrumentation simpler. This is not fully realized as the weir acts as an ordinary rectangular type for low flows. Also, this type of notch is especially liable to clog, making it of little value for the measurement of sewage or industrial waste. In addition, it is difficult and expensive to make, and is not generally recommended.

The Parshall flume is generally manufactured of concrete and full information as to its design and construction is given in reprints, by several instrument manufacturers, of *Farmers' Bulletin No.* 1683, published by the United States Department of Agriculture. The necessity of following the dimensions and design exactly as given cannot be too strongly emphasized. The design has been so simplified that it is not a difficult matter for a good contractor to place the flume in exact accordance with instructions.

The floor of the inlet section is horizontal, whereas the throat section has a decided downward slope, which is followed by an upward-sloping recovery section. Under "free discharge" operating conditions, the liquid flows through the throat section of the flume at critical velocity in a smooth stream. In the recovery section, there is a recovery of head as stream velocity decreases with a resulting rise of level and considerable turbulence. Under these conditions, the rate of flow is a function of only the depth in the upstream channel.

At very high rates of flow, or if the flume is improperly installed, the downstream channel may back up into the throat section. In this case, critical velocity conditions do not exist in the throat section and the flow is a function of both upstream and downstream heads and the difference between them.

As in the case of weirs, theoretical formulas have been derived from hydro-dynamic theory, but the formulas actually used are based on coefficients determined by field experiments.

Speaking generally, the Parshall flume is not as susceptible as are weirs to measurement errors caused by high approach velocities, misalignment of the primary device with the stream axis, and turbulence. The measurement of upstream head must be taken far enough up the throat section to eliminate the gradient due to change in level at the throat section.

The Parshall flume was developed originally for irrigation work because of its low head loss and high overrange capacity. It is used also for measurements of sewage flow and other liquids carrying solids because of its non-clogging and self-scouring characteristics. The flume is much more expensive to build than a weir of equal capacity, but for measurement of sewage and waste flows its two chief advantages—low loss of head and "self-scouring" action—usually far outweigh the extra cost.

There are also available special cast iron flow nozzles, such as the Kennison and parabolic. These have some limited application in measurement of sewage flow, where conditions are such that a Parshall flume cannot be used. They have an advantage over weirs, in that measurement of liquids containing solids is possible without undue clogging. Their chief disadvantages are their high cost (due chiefly to limited applications), and the fact that flow equations are not based on the same extensive experimental data as the standard weirs. In addition, they cannot be constructed easily in the field: being of cast iron, they must be purchased from some manufacturer having the patterns.

Although weirs and Parshall flumes are probably as accurate as orifice plates and Venturi tubes for liquid flow measurement in laboratory use, in field use the errors with these elements are considerably higher. This is true because the variations in application conditions are a much more predictable factor in the case of orifice plates and Venturi tubes installed in pipes. In general, the accuracy of weirs (exclusive of errors in the instruments for measuring heads) is no better than $\pm$ 1½ to 2 per cent of the maximum flow. In laboratory installations where the approach and discharge channels are carefully designed and rating curves are established by test work, an accuracy of better than 1 per cent is easily obtainable. For Parshall flumes installed and used under field conditions, the average accuracy is probably about $\pm$ 3.0 per cent.

Weirs are generally constructed of heavy wood planking, steel plate, or concrete, with thin, detachable metal strips forming the actual weir notch. The notch strips are of a non-corrosive metal, such as bronze, monel, or stainless steel, depending on the liquid being measured. The upstream edge of the strips should be machined to form a sharp, clean 90° angle. It is advisable to bevel the downstream edge of thick strips so as to leave the edge of the notch about 0.050 in. in thickness. Parshall flumes for permanent installation are usually constructed of concrete, with an angle-iron crest at the proper location. As previously mentioned, open flow nozzles are usually constructed of cast iron.

Standard instruments are available for application to flumes and weirs operating over a range of 0 to 30 in. in head flowing over the weir crest. From standard flow discharge tables, it is possible to measure flows from about 10 g.p.m. for V-notch weirs up to flows of many m.g.d. For any given installation, however, the flow range should not be greater than 1 to 10; that is, after setting the maximum flow expected, the minimum flow to be measured accurately should not be less than $\frac{1}{10}$ of the maximum.

It is common practice in measuring flow by weirs and flumes to take off a short length of 12-in. cast iron pipe at the point of measurement to a stilling well. The float for measurement of flow rides on the liquid surface in the stilling well, corresponding to the heighth of flow over the weir or flume crest.

The pipe connecting the flume to the stilling well should be at least 2 in. in diameter and slope slightly upward toward the stilling well. In order that debris and other solids do not obstruct the inlet to the stilling well it is often

advisable to make preparations for a small amount of purge water to drip into the stilling well. The stilling well should be as close as possible to the flume, although there have been occasions where the stilling well has been placed as far as 20 to 30 ft. away.

The float riding on the water in the stilling well is hung from the instrument by means of the proper wire or cord, passing over a pulley and held taut by means of a counterweight. As the float rises and falls, the motion is transmitted through a mechanism to a pen riding on a standard uniform chart, reading directly in units of flow. An integrator can be supplied that will give the total flow passing over the crest. The recording instrument, although installed in weather-proof housing, should be protected by means of additional covering. The instrument is usually installed directly over the stilling well, and in many cases the stilling well can be placed immediately beneath the operating house so that the recording instrument can be easily accessible to the superintendent or engineer.

Both sewage and industrial waste are apt to contain corrosive chemicals. In addition, there is always the danger of corrosive gases in the atmosphere. The measuring instrument is often installed in the open where it is subjected to this corrosive atmosphere as well as the vicissitudes of the weather. The engineer or superintendent should take great care, therefore, in the selection of the instrument to assure its operation under these adverse conditions with a minimum of maintenance. Experience has shown the following precautions advisable:

1. The instrument should be housed for weather protection, regardless of the fact that most instruments are "weather-proof."

2. The float (normally of copper) must be protected by a rubber or plastic coating shown by tests to be impervious to the chemicals in the material to be measured. If a concrete stilling well is used, or other type where the float is apt to be damaged by abrasion, provision should be made for insertion of wooden protection strips. Many plastic materials chip and wear rapidly when subjected to constant abrasion.

3. Great care should be observed in selection of cable connecting the float and recording instrument. Experience indicates that this cable corrodes rapidly and can cause heavy maintenance expense. After much research and investigation, a cable of nylon and glass has been developed to meet practically any condition that may be encountered. This type of cable does not stretch (a most important requirement) and is apparently as resistant to corrosion as is physically possible.

4. The instrument itself should be simple in construction and should record on a uniform chart, both the chart reading and the integrator being so designed as to give direct readings without complicated multipliers.

Many may question the possibility of transmission of the recording and integrating readings from the flume of weir to a central control panel in the pump house or administration building. If a supply of compressed air is available, this reading can be transmitted pneumatically by means of time-proven and dependable instruments. Telemetering electrical transmission is also available.

Either of these transmission systems is applicable to the large plant, where more experienced personnel is available for maintenance. However, the electrical telemetering system, particularly, is expensive and often requires highly experienced service men and engineers for proper installation and maintenance. It is recommended that the operator of a small plant think twice before considering any transmis-

sion system. A simple instrument installed at the weir or flume location, with weather protection, is ample for the small plant.

Measurement of sewage and waste flows by means of weirs or flumes is practical and sufficiently accurate for all sewage flow records, provided care is exercised in construction of the weir or flume. Standard instruments are available for recording and integrating the flow. The total expense of installation is relatively low and the flow records thus obtained are of greater value in plant operation and in calculating sewer rentals.

TIPS AND QUIPS

No Fancy Diving, Please

Like aviators with their famous "Caterpillar Club" for those who have had to parachute from disabled planes, the sewage works fraternity has its exclusive groups of individuals who have complied with the eligibility rules involuntarily. Because many hate to admit that they have become members, any attempt at compiling a complete roster labors under a severe handicap.

Typical of the state-wide groups is the Illinois S.O.W.H.E.S.S. (Society of Operators Who Have Experienced Saturation in Sewage), which made the pages of the 1949 issue of the Central States Sewage Works Association's "Windmill" by welcoming Milo Prentice of Rochelle, Ill., who had fallen into the primary tank. Florida recently organized a unit with the same name, last reported to be growing rapidly.

If such a group exists in Indiana, Marion provided one new candidate during 1948 when, as the plant log reports, ". . . Wally Sult took a try at flying (from top of step ladder to bottom of aeration tank)." Of course the fact that the aeration tank had been drained a week previously and the 6 in. of sludge remaining on the tank bottom was really ripe, did not add to the dignity of the occasion.

Naturally there are always cases of people trying to get into the act, such as one plant superintendent's backflip into the river while attempting to show off a new outboard motor. However, if said superintendent's claims for the efficiency of his plant are valid, his immersion does not count—except as entertainment. At least one spectator wouldn't have missed the sight for any price!

Rubber Covered Impellers

Results of comparative tests on the effectiveness of rubber covered impellers in raw sewage pumps at Gary, Ind., are contained in Superintendent W. W. Mathew's annual report for 1948. The data are indicative of the economy that may be realized with this type of installation.

Sand that has infiltrated into the sewer system at Gary causes excess wear on the raw sewage pump impellers. For more than two years (see THIS JOURNAL, **21**, 1, 151; Jan., 1949) raw sewage pump No. 3 was operated as much as possible, until taken out of service on October 8, 1948, after 9,051 hr. 45 min. of operation. Except at the leading edges of the impeller blades, the condition of the rubber covering was good. The stainless steel blade edges were exposed back to the hub. Adjacent to this leading edge the metal of the impeller blades was also exposed for widths varying from ¼ to ½ in. Approximately 6.75 sq. in. of metal was exposed on each side of an impeller blade back of the leading edge.

The edge of the rubber covering was frayed and worn quite thin. Wear on the rubber coating apparently was governed by the peripheral velocity of the impeller, being greatest at the outer edges of the blades and decreasing toward the hub.

Cost of new impellers and wearing rings averaged $4,102 every 3 years (two installations for each of three units), not including labor in making the change. Assuming that rubber coverings on the three units would have to be replaced every 3 years, the cost on the same basis would be $345.

The test has resulted in the decision to cover all future replacement impellers with rubber before installation, and to replace the rubber coatings whenever necessary.

Wrong Number

Ever been asked to pay the bill for a job you've just done yourself? That's the situation the city of Olean, N. Y., found itself in recently when city forces cleaned out the wrong manhole in response to a report of a cellar flooded by backing up of the sewer.

It seems that the city workers parked their truck in front of the house at 306 instead of 316, and cleaned out the manhole there. No relief being forthcoming the complaining party called plumbers to do the job—and sent the city the $24 plumbing bill!

More Than 'Just Rock'

Not all trickling filter problems result from overloading or adverse operating conditions after the plant is started. Some may be caused by inattention to the specifications for the filter media during construction, as pointed out in "Progress Report No. 22" of the Washington State Pollution Control Commission.

It cost one contractor more than $5,000 to remove, regrade, and replace the filter media at Burlington, Wash., after approximately a year of unsatisfactory operation. At Grandview the stone was changed before the plant went into operation at a much lower cost. What the cost will be at Pullman, which now has the same problem with two 90-ft. diameter filters, is not known.

For trickling filter plants to operate properly the filter media must conform closely to the specifications that have been set up as to size, gradation, and hardness. Contractors seem in many cases to have operated on the principle that "rock is rock" and have just dumped it in the filter, resulting in segregation of the small rock and in chipping and breakage. Undersized media and fine material thus formed may later cause ponding on the filter surface and, consequently, unsatisfactory performance.

The importance of strict conformance to filter media specifications cannot be too strongly emphasized.

Simplified Weighing

Weighing of samples for total residue, calcium, magnesium, silica, suspended solids, total nitrogen, and other water and sewage tests to 0.05 m.g.m. with analytical balance accuracy, but in one-third the usual time, is claimed to be possible by use of a new direct-reading balance. The new balance has only one pan, and the weight reads directly on a scale at eye level, eliminating a usual source of error in adding up individual weights. The balance has all required weights built-in and manipulated by turning four external knobs. No weights are handled; weights less than 0.1 gm. are indicated optically and automatically. Total weight is read directly from a scale on the instrument panel (Figure 1). The sample to be weighed can range from 200 gm. (approx. 7 oz.) to 0.0001 gm.

The knife edges and planes of the balance are sapphire, the pan is gold plated, and the entire case is aluminum with baked lacquer finish. Learning to operate the balance is simple, tests having shown that inexperienced operators can learn to weigh samples in

FIGURE 1.

20 to 25 seconds, after less than one hour's practice. The beam of the balance has a constant load; hence, sensitivity remains constant regardless of the sample size.

Because of its speed and simplicity of operation, the new balance is claimed to be ideal for control tests in water works and sewage plants.

What's in a Name?

To change or not to change the name of the Federation—and of several of the member associations as well—has been the subject of discussion at many a gathering of sewage works and industrial wastes men during the past few years.

The entire controversy as to connotation of the word "sewage" in the public's mind might well be settled by reference to the fact that a postal card showing the Morrison, Ill., treatment plant does not sell too well.

A suggestion has been made that the utility should be renamed "Stream Preservation Works" or, as at Kenosha, Wis., "Water Protection Plant."

Pretty Good Plot

If you really want people to read your annual report take a tip from the 1948 report of operations at Marion, Ind., where D. P. Backmeyer is superintendent. Interspersed throughout his "Log of Important Events" are references to the accident and treatment of Laddie, the plant dog run over by a hit-and-run driver. Nowhere, however, is there any mention of the ultimate disposition of the case by the veterinarian, although the reader's interest is held right to the end by the "human" interest items.

Welcome, Newcomer!

A cordial welcome is extended to the latest addition to the roster of member association publications, "The Integrator" of the Pennsylvania Sewage and Industrial Wastes Association. In his opening editorial (Vol. 1, No. 1, p. 1; August, 1949), editor J. R. Hoffert of the Pennsylvania State Department of Health, Harrisburg, Pa., says the name was chosen because the paper is designed to ". . . integrate the membership into one happy family. . . ."

The Journal wishes the fledgling every success in its endeavors!

Maybe It's Loaded!

A new "miracle" lubricant has been announced that will automatically lubricate plug valves, thus reducing the need for frequent relubrication attention. The lubricant is "energizable," being powered by the pressure exerted in injecting it into the valve. The stored energy is

released later as needed to feed the lubricant into any voids that might occur within the pressurized ducts of the valve system, thus keeping the valve fully lubricated over a long period of time. Savings in man-hours of servicing are expected to be considerable, without any changes in equipment.

The new lubricant is injected into the valve in place of the standard non-automatic lubricant, either by turning down a lubricant screw or by use of a grease gun. It is not necessary to clean or purge the old lubricant from the valve, as it will be forced along gradually until it is exhausted and the valve is fully lubricated by the new. Actuating pressures may be as low as 50 and as high as 1,000 p.s.i.; effectiveness is claimed in temperatures ranging from sub-zero to 250° F.

In short, the new lubricant seems to be capable of forcing its own way into any situation. Possibly it should be nicknamed "Muscles"!

Standard Methods in Technicolor

What is reported to be a "valuable and interesting" laboratory procedure employs new test papers for differentiating between caustic, carbonate, and bicarbonate alkalinity of water and solutions. Three vials of selected indicator papers are now available in a compact and inexpensive kit.

Seems as though we are getting nearer and nearer the point where the prime requisites for anyone running control tests will be a kindergarten diploma and freedom from color blindness!

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Oklahoma Water and Sewage Conference	Stillwater, Okla.	Nov. 9–Dec. 1, 1949
New York State Sewage Works Association	Hotel Statler, New York, N. Y.	Jan. 20–21, 1950
New Jersey Sewage Works Association	Stacy-Trent Hotel, Trenton, N. J.	Mar. 22–24, 1950
Arkansas Water and Sewage Conference	Robinson Memorial Auditorium, Little Rock, Ark.	Apr. 17–19, 1950
Kansas Sewage Works Association	Salina, Kansas	Apr. 20–21, 1950
Michigan Sewage Works Association	Park Place Hotel, Traverse City, Mich.	May 22–24, 1950
Pennsylvania Sewage and Industrial Wastes Association	State College, Pa.	Aug. 23–25, 1950
Iowa Sewage Works Association	Hotel Blackhawk, Davenport, Iowa	Sept. 19–21, 1950

Editorial

THE MONTHLY JOURNAL

This is the last bimonthly issue of the JOURNAL. The January, 1950 issue will inaugurate the new monthly publication schedule, marking another progressive step for the Federation.

The move to monthly publication was demanded by two factors: first, the doubling of publication costs in the period 1941 to 1948, and second, an abrupt 50 per cent increase in material made available for publication as a result of the Federation's expanded service to industrial waste interests. Publication of the present flow of material requires increased revenue from both advertising and membership dues.

In 1941 the JOURNAL printing and mailing budget was $12,000, and the cost of that year's volume came to $7.29 per page. The 1949 budget for this same item is $24,000, and the present cost per page is about $15.50. Our authors today are being requested to condense all manuscripts to minimum length, and many good papers are being released for publication elsewhere, yet editorial space is fully committed for six months ahead.

It is not generally realized that the $3.00 of dues received by the Federation for each Active Member of an affiliated association does not even cover the cost of printing and mailing a JOURNAL subscription. In fact, the cost of printing and mailing the JOURNAL—exclusive of all administrative overhead and editorial costs—has averaged $4.35 per member since 1941! This bargain offering has been possible, of course, only because of the income received from advertising and other sources.

On the basis of the Federation's total annual budget, each Active Member in 1949 will receive about $10.00 in value of publications and services for his $3.00 dues. In 1950, assuming no change in membership, each Active Member will receive the equivalent of $15.00 in value for his personal contribution of $5.00.

The manner in which all Member Associations have accepted the dues increase is truly a compliment to the Federation, even though it is obvious that there is no alternative. The absolute absence of opposition shows strong confidence in the parent organization, and proves the healthy relationship that exists.

Opinions vary as to the probable effect of the dues increase upon the present membership of the Federation. In 1942 when Active Member dues were increased to $3.00 there was a 13 per cent drop in Active Members, but this was recovered within two years. Active membership today is more than double the 1942 level, having topped the long-sought 5,000 mark this year for the first time. The writer holds the opinion that there will be little, if any, loss in membership in 1950, although some hard work must be done in the various Member Associations in order to hold the line. The devaluation of many foreign currencies will have at least a temporary dampening effect on membership in foreign Member Associations.

A word about the new monthly JOURNAL. The issues will not be as large as those at present, of course, for it is planned to carry only about 25 per cent more editorial material in

1950 than this year. There will be no change in editorial policies or in the caliber of editorial content, as there is sufficient high grade material available to afford good selectivity and to require condensation of loosely written copy. From the standpoint of the reader the smaller issues should be advantageous because it will be easier to assimilate the reduced and more frequent "dosages."

Our authors have been most cooperative, and we have deeply appreciated their forbearance during the past three difficult years. We will have continued need for their help and understanding in the early years of the monthly schedule. We will still have to release papers of the "project description" type, unless they are of unusual interest and value. Other papers that might be accepted under other circumstances will be released for lack of originality, inadequacy of data, or because we are already committed to a full supply of papers on the subject, or for similar reasons. We must also conserve space in the monthly issues by asking our authors to make their presentations as "concentrated" as possible, by eliminating all unnecessary coverage and wordage. This is always desirable regardless of space limitations, because the most important findings reported in many technical papers are frequently deemphasized by verbosity.

Early this year a long-time advertiser conducted an extensive readership survey among 630 consulting engineers, municipal engineers, and sewage works superintendents. Of more than thirty sanitary engineering periodicals receiving mention in the returns, THIS JOURNAL was a strong leader in replies to the question "What technical publications do you consider most helpful in your work?" We are indeed proud of this high regard in which the JOURNAL is held by its readership. The survey finding is not mentioned here in a spirit of boastfulness, but rather with full appreciation of our responsibilities in maintaining the high quality of the Federation's principal publication.

The headquarters office staff also has a healthy respect for the magnitude of the monthly publishing operation. Six deadlines a year have been difficult enough to meet, and twelve of them will impose a heavy strain on personnel and facilities, at least until the new routine can be established.

The Federation passed its twenty-first birthday on October 16 of this year. It has grown in size and strength while at the same time its responsibilities have become greater and more varied. Today there is more concern with stream pollution control than there has ever been before, and the opportunity for real accomplishment is here. It is fortunate that the Federation will now have a man-size JOURNAL to carry on its share of the job.

W. H. W.

Proceedings of Member Associations

NEW JERSEY SEWAGE WORKS ASSOCIATION

34th Annual Meeting

Trenton, New Jersey, March 23–25, 1949

The 34th Annual Meeting of the New Jersey Sewage Works Association was held at the Stacy-Trent Hotel, Trenton, N. J., March 23–25, 1949. Of a record attendance of 361, the Association's famous Speechless Dinner and Entertainment, sponsored by the Water and Sewage Works Manufacturers' Association, attracted more than 300, also a record.

Papers presented at the industrial wastes session, held during the afternoon of March 23, were:

"The Waste Disposal Program of a Fine Chemical Manufacturing Plant," by D. J. Cestoni, plant waste disposal engineer, Merck & Co., Inc., Rahway, N. J.

"Stream Pollution Control in Pennsylvania," by F. B. Milligan, industrial wastes division engineer, Pennsylvania Department of Health, Harrisburg, Pa.

"The Consulting Engineer's Place in the Industrial Waste Problem," by Peter Homack, consulting engineer, New York City.

The opening papers of the morning session on March 24, presented under the title "The Manufacturers Speak," were given by representatives of the R. B. Carter Co. and the Warsop Tool Co. These informative talks on new equipment were arranged by A. T. Clark, secretary-manager, Water and Sewage Works Manufacturers' Association, New York City. Other papers during the session on general topics included:

"Control of Bacterial Numbers in Chlorinated Sewage Effluents," by Rolf Eliassen and Herman L. Krieger, professor of sanitary engineering and research assistant, respectively, College of Engineering, New York University, New York City;

"Plainfield Takes a Forward Step in the Administration of Sewage Systems," by Joseph D'Agostino, councilman, Plainfield, N. J.; and

"How Ground Garbage is Expected to Influence Sewage Works at Greenwich, Conn.," by J. Doman, sanitary engineer, Department of Public Works, Greenwich, Conn.

After greetings from the Federation by Vice-President A. H. Niles, engineer-superintendent, Department of Public Service, Toledo, Ohio, the afternoon session was devoted to two papers as follows:

"Organization of the Bergen County Sewer Authority," by Donald A. Quarles, chairman, Bergen County—Hackensack River Sanitary Sewer District Authority.

"Proposed Raritan Valley Trunk Sewer and Treatment Works," by George F. Smith, chairman, Middlesex County Planning Board.

At the business meeting on the morning of March 25, the Association voted to increase its dues in 1950 to meet the requirements of the Federation. Officers elected for 1949–50 were:

President: John Struss, Wildwood.
Vice-President: Sol. Seid, New Brunswick.

Secretary-Treasurer: M. S. Kachorsky, Manville.

FSWA Director: L. J. Fontenelli, Rahway.

To close the meeting a paper, "Ten Years of Sludge Digestion Experience at the Rahway Valley Sewage Treatment Plant," was presented by L. J. Fontenelli, superintendent, Rahway Valley Joint Meeting.

M. S. KACHORSKY,
Secretary-Treasurer

ARIZONA SEWAGE & WATER WORKS ASSOCIATION

1949 Spring Conference

Prescott, Arizona, April 1–3, 1949

Despite the vagaries of the weather, bringing an unusual April snowstorm to Arizona, 133 members and guests gathered in Prescott, April 1–3 for the 1949 Spring Conference of the Arizona Sewage and Water Works Association.

The first technical session, under the leadership of President John Rauscher, was opened by a discussion on "Removal of Fluorides from Water Supplies" by George Swem, The Permutit Company. The remainder of the morning session was devoted to a discussion of the public relations problems in both the sewage and water works field. W. H. Wisely, Executive Secretary of the Federation, spoke of personal experiences as an operator. Both he and John C. Luthin, water superintendent, Santa Cruz, Calif., who discussed this topic, stressed the importance of maintaining good public relations with the individual customer as well as with the public as a whole.

Reports from the F.S.W.A. and A.W.W.A. were featured at the Friday luncheon.

Walter Harford's informal discussion of concrete pipe followed the luncheon meeting, and dealt with the manufacturer and use of different types and connections for pressure concrete pipe. In his paper, "Septic Tank Design and Performance," Harvey F. Ludwig, Los Angeles consulting engineer, outlined studies being made in this field and discussed septic tank design which departs somewhat from the conventional design now in use. M. E. Devine, Tucson Water Department, discussed his successful efforts in "Repair of Reservoirs." The Friday session was concluded with a panel discussion, led by A. W. Miller, of such topics as in-service training of water and sewage works personnel, the value of A.W.W.A. specifications, the use of F.S.W.A. and A.W.W.A. public relations material, and short schools for operators.

Byrl D. Phelps, San Diego consulting engineer, was toastmaster at the Friday night dinner. A feature of the program was the presentation of a color portrayal of the proposed Central Arizona irrigation project.

The Saturday morning session opened with a business meeting at which the following officers were elected for 1949–50:

President: A. Anton Frederickson, Pima.

1st Vice-President: Geo. W. Marx, Phoenix.

2nd Vice-President: John Hoover, Mesa.

Secretary: Mrs. Helen Rotthaus, Phoenix.

Following the business meeting, T. R. Mackay, chief engineer, Fairbanks-Morse Company, discussed "Horizontal and Vertical Pumps and Their Applications"; F. G. Nelson, The Dorr

Company, gave his "Thoughts on Sludge Digestion"; and the morning session was concluded by a history and description of the Prescott water supply, presented by Cecil Overstreet, Prescott city engineer, and Stuart P. Henderson, water superintendent.

Rev. Charles F. Parker was the speaker at the Saturday luncheon. Using the familiar slogan, "Silent Service is Not Enough," he pointed out that the community should be made aware of the services rendered by municipal utilities. Lauding the continuing program of expansion and improvement in the industry, he urged that a good public relations program be utilized by privately and municipally owned utilities and stated that "publicity should be as strong as chlorine and as palatable as maple syrup."

The operators met in closed session Saturday afternoon to discuss mutual problems of operation. Thirty were in attendance at this "Roundup." The parallel session held that afternoon heard Richard Bennett, engineer, City of Phoenix, discuss developments in sewer design. John C. Luthin led a panel discussion on "Cost Engineering in Water Works Practice." A. M. Rawn, chief engineer, Sanitation Districts of Los Angeles County, spoke on "Recent Sewage Disposal Developments" and discussed the problem of disposal of atomic wastes. He outlined a process of purification by compressed air in place of disinfectants.

Members and guests assembled Saturday evening in the lobby of the Hassayampa Hotel at a cocktail party given under the sponsorship of Water and Sewage Works Manufacturers' Association members, who also provided dancing following the dinner. Informality and hilarity was the keynote of the traditional dinner under the guidance of the Select Society of Sanitary Sludge Shovelers.

MRS. HELEN ROTTHAUS,
Secretary

PACIFIC NORTHWEST SEWAGE WORKS ASSOCIATION

16th Annual Meeting

Bellingham, Washington, May 11, 1949

At the 16th Annual Meeting of the Pacific Northwest Sewage Works Association, held at the Hotel Bellingham, Bellingham, Wash., May 11, 1949, the following officers were elected for 1949–50:

President: Emil C. Jensen, Seattle, Wash.

1st Vice-President: W. P. McNamara, Seattle, Wash.

2nd Vice-President: Wm. W. Tinniswood, Moscow, Idaho.

Secretary-Treasurer: Wm. P. Hughes, Lewiston, Idaho.

Other business included unanimous passage of constitutional changes to increase the Associations' dues in conformity with the Federation's 1950 schedule and of an investigating committee's recommendation to license operators by voluntary methods.

The morning technical session opened with a symposium on "Status of Water Pollution Control in the Pacific Northwest." Developments in the four political divisions of the Association's area were presented by H. C. Clare, director, Division of Public Health Engineering, Idaho State Department or Public Health, Boise; Curtis M. Everts, Jr., secretary and chief engineer, Oregon State Sanitary Authority, Portland, Ore.; Reginald Bowering, public health engineer, Provincial Board of Health, Victoria,

B. C.; and E. F. Eldridge, acting director, State Pollution Control Commission, Olympia, Wash. This was followed by a plant operation panel featuring papers as follows:

"Economics Derived from Laboratory Analysis," by R. O. Sylvester, assistant professor of civil engineering, University of Washington.

"Plant Safety," by R. E. Leaver, public health engineer, Washington State Department of Health.

"Make Your Chlorination Pay Dividends," by Harry A. Faber, research chemist, The Chlorine Institute, New York City.

"Gaining Community Interest," by L. L. Sphar, consulting engineer, Seattle, Wash.

Discussion leaders at the Operators' Forum Luncheon were Frank E. Mathews, Ellensburg, Wash.; W. W. Tinniswood, Boise, Idaho; Wallace Green, Gresham, Ore.; and Harry Crow, Kirkland, Wash.

Papers presented at the afternoon session were:

"The New Federal Pollution Control Bill," by R. R. Harris, Sr., sanitary engineer, U. S. Public Health Service, Portland, Ore., and L. R. Durkee, division engineer, Federal Works Agency, Bureau of Community Facilities, Seattle, Wash.

"Alcohol Production During Waste Disposal," by Donald L. Reed, alcohol plant superintendent, Puget Sound Pulp & Timber Co., Bellingham.

A directed tour of the Bellingham sewage treatment plant was a highlight of the meeting.

WILLIAM P. HUGHES,
Secretary-Treasurer

NEW ENGLAND SEWAGE WORKS ASSOCIATION

Spring Meeting

Bristol, Connecticut, May 25, 1949

The Twentieth Anniversary Spring Meeting of the New England Sewage Works Association, held at Lake Compounce, Bristol, Connecticut, on May 25, 1949, was attended by 163 members and guests. The morning program, presided over by President Walter H. Brown, Jr., was devoted to the following technical papers:

"Disposal of Dye Washing Wastes," by Joseph A. McCarthy, chief of laboratory, Lawrence Experiment Station, Mass. Department of Public Health.

"Use of Lime in Digestion Compartment of Imhoff Tanks and Unheated Digestors," by J. Henry L. Giles, senior sanitary engineer, Connecticut Department of Health.

"Use of Transite Pipe for Sewers," by Roger W. Esty, superintendent of water and sewers, Danvers, Mass.

"Digestion Characteristics of Industrial Wastes Containing Starches," by Rolf Eliassen, professor of sanitary engineering, New York University.

Following luncheon, James P. Casey, Mayor of Bristol, extended the greetings of the city to the members and guests present, and made a few appropriate remarks concerning the city's new sewage treatment plant.

C. M. Pfennig, city engineer of Bristol, opened the afternoon program with a paper, "Sewage Problem at Bristol." He was followed by Past President Frank L. Flood, of Metcalf and Eddy, whose topic was "Bristol Sewage Treatment Plant, Design and Operation."

The meeting then moved from Lake Compounce to the new Bristol sewage treatment plant, nearing completion.

WALTER E. MERRILL,
Secretary-Treasurer

CENTRAL STATES SEWAGE WORKS ASSOCIATION

22nd Annual Convention

Chicago, Illinois, June 17–18, 1949

The 22nd Annual Convention of the Central States Sewage Works Association was held at the Hotel Sherman, Chicago, Ill., June 17–18, 1949. Total registration for the meeting included 231 members and guests, plus 43 ladies, who were welcomed on behalf of the City of Chicago and the Chicago Sanitary District by Casimir Griglik, vice-president and chairman, Finance Committee, Sanitary District of Chicago.

The technical sessions on June 17 included the following papers:

"Biological Treatment of the Spent Liquor from the Sulfide Pulping Process," by Jess M. Holderby, coordinator, Sulfide Pulp Manufacturers Research League, Appleton, Wis.

"The Future of Domestic Garbage Disposers," by Mark B. Owen, consulting engineer, Indianapolis, Ind.

"Some Temperature Effects on Sewage Filtration," by George J. Schroepfer, professor of sanitary engineering; Bahhij Al Hakim, graduate student; Harris F. Seidel, instructor; and Norman R. Ziemke, graduate student, all of the University of Minnesota.

"Disposal of Sewage Effluent at Madison, Wis.," by Herbert O. Lord, chief engineer, Madison Metropolitan Sewage District, Madison, Wis.

"Correlation of the Sanitary Survey and the Coliform Enterococci Levels in a Lake Pollution Investigation," by R. S. Nelle and R. M. Scott, principal sanitary engineer and bacteriologist, respectively, Sanitary Water Board, Springfield, Ill.; and C. W. Klassen and W. A. Hasfurther, chief sanitary engineer and principal sanitary engineer, respectively, State Health Department, Springfield, Ill.

A technicolor film entitled "A Tale of the Twin Cities" was then presented and explained by Kerwin L. Mick, chief engineer and superintendent, Minneapolis-St. Paul Sanitary District, St. Paul, Minn.

A "Club Room" sponsored by the Water and Sewage Works Manufacturers' Association occupied the hour preceding the Annual Banquet, which was entirely free of speeches and business. After-dinner entertainment was provided in the form of dance acts, an unusual magician's act, and a table tennis exhibition. Dancing and cocktails were enjoyed later in the evening, also under the sponsorship of the Water and Sewage Works Manufacturers' Association.

The morning session on June 18 was devoted to an "Operators' Breakfast," in which open discussion from the floor was stimulated and guided by a panel consisting of Don E. Bloodgood, professor of sanitary engineering, Purdue University; C. C. Larson, chemist, Springfield (Ill.) Sanitary District; George W. Martin, superintendent of sewage treatment, Green Bay, Wis.; M. L. Robins, chemist, Minneapolis-St. Paul Sanitary District; S. C. Martin, Great Lakes basin engineer, U.S.P.H.S., Chicago; and Walter A. Sperry, superintendent, Aurora (Ill.) Sanitary District. Most of the discussion period was devoted to oil troubles in sewers and treatment plants and to personnel and public relations.

At the business meeting, held in connection with the Annual Luncheon, constitutional amendments were passed to conform with the 1950 dues increase of the Federation.

Officers elected for 1949–50 were:

President: L. S. Kraus, Peoria, Ill.
1st Vice-President: H. T. Rudgal, Kenosha, Wis.

2nd Vice-President: M. L. Robins, St. Paul, Minn.

3rd Vice-President: W. W. Mathews, Gary, Ind.

Secretary-Treasurer: Paul W. Reed, Indianapolis, Ind.

Following adjournment of the meeting, many of the delegates enjoyed an interesting and informative inspection trip to the Southwest sewage treatment works, under the guidance of J. M. Mercer, assistant civil engineer, Sanitary District of Chicago.

PAUL W. REED,
Secretary-Treasurer

LOUISIANA CONFERENCE ON WATER SUPPLY AND SEWERAGE

1949 Annual Meeting

Baton Rouge, Louisiana, June 29–July 1, 1949

The 1949 Annual Meeting of the Louisiana Conference on Water Supply and Sewerage was held at Louisiana State University, Baton Rouge, June 29–July 1, 1949, in conjunction with the Twelfth Annual Short Course for superintendents and operators of water and sewage systems. Total attendance was 71.

At the Annual Banquet of the Conference, held the evening of June 30, the Sewage Works Section, created by constitutional amendments adopted March 5, 1949, elected the following as officers for 1949–50:

Chairman: Joseph Cefalu, Morgan City.

Vice-Chairman: B. S. Graves, Norco.

Secretary: D. L. Winters, New Iberia.

FSWA Director: S. S. Crawford, Lake Charles.

At the banquet, talks were made by George S. Russell, past president of the Federation, and Morrison B. Cunningham, AWWA director for the Southwest Section. A. A. Hirsch, State Department of Education, reported on "Itinerant Schools."

Papers of special interest to sewage works members during the opening session on June 30 included:

"The New State Plumbing Code," by John L. Porter, assistant director, Division of Public Health Engineering, Louisiana State Health Department.

"Pollution of Streams by Domestic Sewage," by William A. Moggio, research associate, Engineering Experiment Station, Louisiana State University.

At concurrent afternoon sessions on water and sewage, water supply papers dealing with the subjects of fire flows, pipe joint materials, and odor and taste in surface supplies were presented. Papers in the sewage section included:

"Garbage Grinding—Effects on Sewers and Sewage Disposal Plants," by John E. Trygg, chief, Water Supply and Waste Disposal Section, Louisiana State Health Department.

"Scum Control in Digestion Tanks," by George Sallwasser, assistant regional engineer, Louisiana State Health Department. An inspection visit to the Greenwell Springs Hospital sewage disposal plant followed.

In the evening, films were shown of water supply and sewage activities, after which a panel composed of Professor Pillet and Messrs. Trygg and Hirsch conducted a "Question Box" period for discussion of problems.

A joint opening session on June 30 heard a paper on "Financing Sewer-

age and Water Supply Improvements," by J. L. Swanson, consulting engineer, J. J. Holtgreve, general manager, Jefferson Sewerage District No. 1, and Willis C. McDonald, assistant district attorney, Jefferson Parish. Thereafter, the meeting again divided into concurrent sessions on water and sewage. Water works papers dealt with elementary hydraulics, emergency chlorination, iron and manganese removal, and meters. Papers at the sewage section included:

"Sewage Flow Measurements," by A. B. Ritter, regional engineer, State Health Department.

"Sewage Chlorination, Emergency B.O.D. Reduction, and Odor Control," by A. J. Gully, graduate assistant in chemistry, L. S. U.

"Sewage Effluent Reclamation," by A. J. Szabo, regional engineer, State Health Department.

"Operating a Dilapidated System," by S. Hazlip, chemist, sewage treatment plant, Houma.

The afternoon was devoted to discussion of operating problems, led by J. J. Holtgreve, and a demonstration and discussion of mechanical trenching equipment by L. C. Eldridge, superintendent, Baton Rouge Water Works Co.

July 1 was devoted entirely to examinations for water and sewage operators' certification.

ALABAMA WATER AND SEWAGE ASSOCIATION

Fourth Annual Meeting

Tuscaloosa, Alabama, June 9–11, 1949

The Alabama Water and Sewage Association held its Fourth Annual Meeting and Short School at the University of Alabama, Tuscaloosa, June 9–11, 1949. For the first time, during the two afternoon periods separate sessions were held for water and sewage plant operators. The total registration hit a new high of 126.

On the afternoon of June 9, C. L. Gray, operator of the Ensley sewage treatment plant, Jefferson County, discussed primary treatment, after which R. C. Barton, sanitary engineer, Jefferson County, discussed sludge digestion and sludge drying beds.

The following afternoon, after a general session demonstration of bacteriological technique by Miss Ellen Howell, director, Tuscaloosa Branch Laboratory, Alabama Department of Public Health, W. F. Chandler, Jr., chemist-operator, Shades Valley sewage treatment plant, Jefferson County, demonstrated chemical control tests for sewage treatment plants.

Other talks of interest to sewage plant operators included a discussion of "Basic Plant Electricity and Equipment," by John L. Snow, district engineer, Layne Central Co.; and "Safety in Water and Sewage Works," by G. H. Dunstan, associate professor of sanitary engineering, University of Alabama. J. C. Clarke, director, Alabama Water Improvement Advisory Commission, gave a progress report on "Stream Sanitation." John E. Gran, associate professor of chemistry, University of Alabama, continued his series of talks on chemistry. V. M. Ehlers, president of the Federation, was present and discussed Federation affairs.

A. O. Taylor, Auburn, served as toastmaster at the banquet on the evening of June 10, with George E. Symons, associate editor of *Water and Sewage Works*, as principal speaker.

The sewage section by-laws were amended to increase the dues in 1950 in accordance with Federation action.

Officers elected for 1949–50 were as follows:

President: George H. Godwin, Decatur.

Vice-President: John Staleup, Mobile.

Secretary: A. O. Taylor, Auburn.

Treasurer: G. H. Dunstan, Tuscaloosa.

G. H. DUNSTAN,
Treasurer

CALIFORNIA SEWAGE WORKS ASSOCIATION

1949 Annual Meeting

Stockton, California, May 19–21, 1949

The 1949 Annual Meeting of the California Sewage Works Association was held at the Hotel Stockton, Stockton, Calif., May 19–21, 1949. A total of 184 persons registered for the convention.

The morning technical session on May 19 was devoted to a symposium on "Progress of Sewage Treatment," for which Charles Gilman Hyde, consulting sanitary engineer, Berkeley, was moderator. Subjects discussed by the various panel members were:

"Methods of Handling Screenings," by Marvin Anaya, civil engineer, Bureau of Engineering, City-County of San Francisco.

"Oxidation Ponds," by D. H. Caldwell, consulting engineer, San Francisco.

"The Vacuator Solves Scum Problem at Palo Alto," by R. P. Logan, research engineer, Dorr Company.

"Researches in Sewage Treatment," by Harold B. Gotaas, professor of sanitary engineering, University of California, Berkeley.

"Sewage Works Planning and Construction in the East," by W. H. Wisely, Executive Secretary, FSWA.

An afternoon field trip to the Stockton sewage treatment plant, which handles large volumes of fiberboard and cannery wastes, was followed in the evening by a social get-together and buffet sponsored by the Water and Sewage Works Manufacturers' Association.

Sessions on May 20 opened with a Chemists' Breakfast and an Operators' Breakfast running concurrently and presided over by Harvey Ludwig, consulting engineer and chemist, Pasadena, and A. E. Fiscus, chief operator of the Terminal Island sewage treatment plant, Los Angeles. This was followed by a very interesting Operators' Forum, presided over by A. E. Fiscus, in which the major topics of discussion included operation of institutional plants, methods of handling overloading, and effects of industrial wastes. The remainder of the morning session was devoted to the following papers:

"Improvements in Sewage Treatment by City of Stockton," by J. Don Layson, sanitary engineer, Stockton.

"Proposed Sewage Treatment Program for the City of Sacramento," by Richard Kennedy, consulting engineer, San Francisco.

At the Annual Business Meeting and Luncheon, constitutional amendments were adopted increasing the dues in accordance with the schedule of the Federation for 1950, when the JOURNAL becomes a monthly publication.

Officers elected for 1949–50 were:

President: Raymond R. Ribal, Oakland.

1st Vice-President: Frederick G. Nelson, Los Angeles.

2nd Vice-President: Harold B. Gotaas, Berkeley.

Secretary-Treasurer: Lawrence H. Cook, Menlo Park.

In the afternoon session on May 20, Danilo Prodanovitch, engineer, East Bay Municipal Utility District, presented slides and discussed the construction activities of the District. A similar presentation was made on the current major construction projects of the Los Angeles County Sanitation Districts by John Parkhurst and Richard Gilman, engineers with the Districts. A panel discussion on "Construction Costs and Trends," under the chairmanship of Raymond R. Ribal, drainage engineer, City of Oakland, followed. Panel members and their topics included:

"General Construction," by Robert Rothschild, contractor, San Francisco.

"Mechanical Installations," by L. A. Cline, United Concrete Pipe Corp., Stockton.

"Equipment Costs," by Harvey Eastling, Link Belt Co., San Francisco.

Main speaker at the Annual Banquet and Dance was G. L. Fox, manager of the San Francisco Chamber of Commerce, whose subject was "Selling Municipal Projects to the Public."

The morning of May 21 was devoted to discussions of general interest as follows:

"Financing Industrial Waste Collection and Disposal," Richard Bartle, engineer, League of California Cities, moderator.

"Collections Systems," Earl R. Bunting, assistant superintendent, Bureau of Sewer Maintenance and Repair, City and County of San Francisco, moderator.

"A Discussion of Findings in *Explosive Hazards in Underground Structures*," by W. M. Henderson, superintendent of distribution, Southern California Gas Co.

"Personnel," by H. S. Kaulbach, maintenance engineer, City of Oakland.

"Use of Sewage Effluents in Southern California," by A. M. Rawn, chief engineer and general manager, Los Angeles County Sanitation Districts.

LAWRENCE H. COOK,
Secretary-Treasurer

MONTANA SEWAGE WORKS ASSOCIATION

Fifth Annual Meeting

Great Falls, Montana, April 7, 1949

The Fifth Annual Meeting of the Montana Sewage Works Association was held in the City Council chambers at Great Falls, Montana, April 7, 1949. A new record for attendance was set with 60 registrations.

The one-day technical program included papers on many subjects of interest to sewage works men. The usual social functions were held in conjunction with the Montana Section of A.W.W.A.

At the business meeting it was voted to circulate a mail ballot to the Association membership amending the by-laws to comply with the January, 1950, change in Federation dues.

Officers elected for 1949–50 were:

Chairman: Chet Eyer, Billings.

Vice-Chairman: Kurt Wiel, Miles City.

Secretary-Treasurer: H. B. Foote, Helena.

H. B. FOOTE,
Secretary-Treasurer

Reviews and Abstracts*

Report on Waste Disposal. *Chemical Engineering*, **56**, 3, 95–119 (March, 1949).

In an editorial foreword serious water supply and waste disposal problems at a pharmaceutical plant are cited. Plant location is an important factor. The editorial concludes that the first step toward the solution of industrial water supply and waste disposal problems is to assume the broader responsibility that "comes with the recognition of water supply and waste disposal as the beginning and end of every manufacturing process." Following this there is need "for precise planning, efficient design, and careful, conscientious operation and maintenance." The report continues with sections on waste disposal problems as follows:

Waste Disposal. By W. J. Eldridge.

To obtain effective results on pollution abatement the person responsible for this program should be high enough in the concern's organization to help make decisions on policy matters and expenditures. For effective control an industry should set two goals: avoidance of new sources of pollution and improvement in waste disposal practices at existing locations. Pollution control must be considered at every step in research, design, and operation. A competent staff should be assigned to the work of pollution control. Plant and stream surveys should be conducted. Results achieved should be publicized. Special consultants should be retained as necessary. A friendly working relationship should be established between the industrial pollution control staff and representatives of governmental stream control agencies. There should be a free exchange of information on waste treatment methods between companies.

The Ohio Valley Program Marks a Trend and Points a Moral. By Editorial Staff.

In July, 1948, eight states in the Ohio basin signed the Ohio River Valley Water Sanitation Compact to set in motion a 15-year, $400,000,000 municipal and industrial pollution control program. At the same time, the President signed the Barkley-Taft Water Pollution Act. Industry should take full cognizance of the importance of these acts and begin careful study and action on its pollution problems.

Reduction of industrial waste pollution is generally accomplished by one or more of the following: plant changes, treatment with municipal sewage, and treatment in special plants. The last method is used when the first is insufficient and the second is impractical.

The article continues with summaries on oil refining, tanning, distillery and by-product coke wastes.

Don't Throw Troubles to the Winds. By V. L. King and R. J. Jenny.

An account of air pollution prevention practices at the Bound Brook, N. J., plant of the Calco Chemical Co. This company has spent over $700,000 in the last 10 years on over 200 installations for the suppression of air pollution.

Dispose of Pickle Liquor at a Profit. By Harry Kraiker, Jr.

The process, involving the use of zinc and pickle liquor wastes, is described in the text and by means of a pictured flow sheet. Zinc and pickle liquor wastes react with chlorine to form $Fe(OH)_3$, $ZnSO_4$, and $ZnCl_2$. All of these products are marketable and the operation is a profitable one. The raw materials used are spent pickle liquor, chlorine, and zinc wastes. Of the thousands of gallons of pickle liquor that

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

enter this new chemical plant none will be discharged to streams.

Atomic Wastes. ANON.

Conclusions drawn from a seminar conducted by the U. S. Atomic Energy Commission are: "(1) Bombardment by heavily charged particles is the only way to induce radioactivity . . . ; (2) Where there is radioactivity there is no chemical or physical means of getting rid of it . . . ; (3) One method of solution involves hitting the problem at the source—better planning and insulation, and thus fewer 'hot' wastes; and (4) Pure disposal can be satisfactorily handled by proper application of conventional equipment and procedures." Wastes are now being handled by dilution and storage, and by burial. Dilution and storage can be applied to wastes of low intensity with short half-lives. After dilution and storage these wastes are released to streams or to the atmosphere for even greater dilution. "Hot" long-lived wastes can only be buried. Elaborate checks are employed by the A.E.C. to prevent accidental loss of dangerous wastes.

In the case of water-cooled reactors, the water is first filtered to remove most of the impurities, as those that remain become active while passing around the pile. The "hot" water is then allowed to decay in underground storage tanks, after which it passes to a large holding pond. At Oak Ridge, water from the holding pond is discharged into a lake and stream. The discharge is controlled by three criteria: (1) maximum average daily discharge 5 curies, with a week's limit of 35 curies; (2) radiation level of water cannot exceed 10 millireps a day; and (3) dilution factor at entry into stream (range 20 to 1,000). The final concentration is far below the maximum safe concentration. Radiation decay in the lake is such that only one-fourth of the cumulated activity remains after one year. Much of this is concentrated in the mud and algae at the bottom of the lake. The water of the river is less radioactive than that in many mineral springs. Other wastes discharged into the Tennessee Valley waters show no greater concentration than one microcurie per liter. Much study is being given to the activated sludge process. Activated sludge offers a vast surface for sorption of radioactive materials. Bacteria in the sludge seem to thrive in water of rather high activity. Experiments indicate that 95 per cent of up to 1.4 micrograms of uranium or plutonium per liter can be removed by the sludge. It is estimated that in two stages a 99 per cent removal could be obtained.

Current plans for waste disposal include closed-cycle incinerators, cooling systems, an evaporation method, and ion exchange resins. Chemical precipitation methods are also under study.

Gaseous Wastes. BY ARTHUR E. GORMAN.

Sources of radioactive waste which may cause atmospheric contamination are: (1) material processing, (2) metallurgy and machining, (3) air-cooled nuclear reactor operations, (4) chemical separations, (5) laboratory research, and (6) incineration. The tentative permissible limit of atmospheric contamination by alpha-emitting materials in working areas has been established at 5×10^{-7} micrograms, or 3×10^{-8} microcuries per liter of air. Certain operations are not carried out when meteorological conditions are unfavorable; elaborate meteorological facilities are provided in the production areas. Radioactive iodine was found to be an important air contaminant. The permissible limit of this substance in air is 3.5×10^{-5} microcuries per liter. It should not exceed 0.2 microcuries per kilogram in vegetables. Projects involving study of problems of the disposal of gaseous effluents are now under way.

Liquid Wastes. BY W. A. ROGER.

This paper presents a summary of activities and problems in connection with the disposal of liquid wastes from atomic energy plants. The aim of the Atomic Energy Commission is to discharge no radioactivity to nature. Practically, this is a difficult goal. Tolerances will be set probably at or near the natural backgrounds for the areas involved. It is believed that the waste disposal problems can be solved by the use of conventional unit operations and commercially available equipment.

Federal Waste Law. BY EDITORIAL STAFF.

This article presents a review of the Water Pollution Control Act (Public Law 845). PAUL D. HANEY

Spectrophotometric Determination of Hydrogen Sulfide. By James K. Fogo and Milton Popowsky. *Analytical Chemistry*, **21**, 6, 732–734 (June, 1949).

The method described is one for the determination of hydrogen sulfide in gases. With modification it could also be applied to sewage. In the procedure developed, hydrogen sulfide is absorbed from a stream of gas in a suspension formed by adding sodium hydroxide to a solution of zinc acetate. The stripped gas is metered. The suspension containing the absorbed sulfide as zinc sulfide is treated with an acid solution of p-aminodimethylaniline, followed by ferric chloride solution. After formation of the methylene blue a suitable aliquot is transferred to a spectrophotometer for measurement of the optical density of the blue solution. This measurement is normally made with light of 670 millimicron wave length, at which sensitivity is the greatest. The quantity of sulfide is then read from a previously prepared calibration curve. The method is sensitive to about 3 micrograms. The procedure is convenient for occasional as well as frequent use.

Paul D. Haney

Determination of Oil in Oil Field Waste Waters. By H. D. Kirschman and Richard Pomeroy. *Analytical Chemistry*, **21**, 7, 793–797 (July, 1949).

Oil is considered to be the relatively nonvolatile, liquid component of oil field waters that contributes to the formation of oil films and deposits. The nonsaponifiable hexane-soluble fraction most closely represents the oil content according to this definition. Naphthenic acids are extracted with oil and must be separated by saponification. A procedure which is based on flocculation extraction, air drying, and weighing of the air dried extract gives results which differ by an average of less than 1 p.p.m. on duplicate samples. Ferric chloride is unsuitable as a flocculating agent because it produces sulfur in the extract if the waste water contains sulfide. Zinc acetate is satisfactory. Results by the flocculation method check well, but are about 2 p.p.m. lower than those obtained by the wet extraction method. The wet extraction method gives results of superior accuracy in less elapsed time and the authors consider it generally preferable.

Paul D. Haney

Aeration of Soluble Organic Wastes with Nonflocculent Growths. By H. Heukelekian. *Industrial and Engineering Chemistry*, **41**, 7, 1412–1415 (July, 1949).

This paper describes a process of aerating concentrated, soluble, nontoxic, organic wastes which involves return to the raw waste of the liquid in which the biological growth is dispersed. The process is simple and easily controlled. Volume of seed and pH of the waste are not critical. Foaming difficulties will be encountered with certain types of wastes. Wastes deficient in phosphorous and nitrogen will require supplementation. The adaptability of a particular waste to such a process can easily be tested in the laboratory. This treatment will produce B.O.D. reductions of up to 70 to 80 per cent for wastes having a B.O.D. of 4,000 p.p.m. and may prove useful as a "roughing" type of treatment. With weaker wastes (1,000 p.p.m. B.O.D.), reductions in B.O.D. of 90 per cent are obtained.

Paul D. Haney

Problems of Radioactive Waste Disposal. By Forrest Western. *Nucleonics* **3**, 2, 43–49 (Aug., 1948).

The chemical, toxic, and hazardous characteristics of representative radioactive elements arising from the production of fissionable materials, the use of radioisotopes for experimental purposes, and the use of fissionable material in warfare are discussed with respect to waste disposal problems. The principal methods of waste disposal are: (a) dilution with water; (b) dilution with stable isotopes; (c) storage of short lived radioisotopes until decayed; (d) concentration of wastes to convenient volumes from process fluids by ion exchange, adsorption, precipitation, solvent extraction, and evaporation to achieve more economical storage for (c); or (e) continuous storage in containers or solid concrete blocks at some location such as the bed of an ocean. The limitations of these methods are indicated in four tables of the radioactive characteristics of some elements and one table of the "tolerance" concentrations of various radioisotopes in drinking water. Importance is attached to the necessity of monitoring air and water suspected to contain radioactive substances.

L. R. Setter

Review of Basic Methods for the Utilization of Refuse Under Polish Conditions. By STANISŁAW WARZECHA. *Gaz, Woda i Technika Sanitarna* (Polish), **23**, 11 (Jan., 1949).

Several systems of refuse disposal are discussed in detail, with cost analyses to show variations in the cost of disposal. Computed costs for each of the systems considered are given in Table I. (Cost data have been converted at the rate of 5.18 prewar Polish zloty to one American dollar.)

TABLE I.—Comparison of Refuse Utilization Systems Under Polish Conditions

Method of Treatment	Area Required	Construction Cost ($ per cu. meter[1])	Operating Cost ($ per cu. meter[1])	Product
Incineration	Small	$3,860	$1.16–1.55	Electrical energy
Klimowicz incinerator	Small	$ 386		Chemicals and insulating material
Beccari cells	Large	$ 965	$0.29–0.386	Fertilizer (low temp.)
Picco cells	Fairly large	$ 965	$0.29–0.386	Fertilizer (low temp.)
Dano process	Fairly small	$1,160	$0.29–0.386	Fertilizer
Discharge to sewers	Sewage treatment plant	$ 57.90	$0.0386[2]	
Discharge to sewers at selected points	Sewage treatment plant	$ 193	$0.0483[3]	Fertilizer (low temp.)
Discharge at sewage treatment plant	Sewage treatment plant	$ 193	$0.0483	

[1] Of waste processed.
[2] $2.51 per householder.
[3] Minimum.

The author concludes that the conversion of refuse to electrical energy by means of incineration is not economical, as electricity produced by this method is twice as costly as that produced from coal.

In the Klimowicz method the refuse is incinerated and phosphorous is recovered from the ash. The heat produced during incineration may be utilized for heating and other purposes, and the ash remaining after phosphorous extraction may be used as an insulating material. It is claimed that the sale of the recovery products will cover incinerator operation, although no data are available.

The author next considers fermentation as a means of disposal, and discusses controlled dumping, composting, the Beccari process, the Picco process, and the "Dano" process. Of the processes mentioned, the first three are well known here. The Picco process differs from the Beccari process in that the fermentation cells are 16.4 ft. high, rather than approximately 10 ft. high, and the refuse is digested with the aid of air pressure. This method has the advantage of smaller space requirements for a given volume.

In the "Dano" system, developed in Denmark, the refuse passes through stages —namely, sorting, mixing, comminution, and secondary mixing. The end product, a compost-like material called "Dano," is homogenous, granular, devoid of unpleasant odors, and high in fertilizer content. Chemical analyses compare with those for manure and liquid fertilizer as follows:

Chemical Constituent	Manure	Liquid Fertilizer	Dano
N (%)	0.45–0.67	0.75	0.75–0.82
P_2O_5 (%)	0.32–0.39	0.32	0.26–0.59
K_2O (%)	0.35–0.46	0.26	0.15–0.22
Total	1.12–1.52	1.33	1.16–1.63

Placed in layers, Dano ferments in much the same manner as refuse in Beccari cells, but at temperatures exceeding 60° C. It is possible to conserve the heating property of this fertilizer by the addition of certain chemicals to delay fermentation. No data are available under Polish operating conditions. The Dano method may be applied also to the treatment of liquid manures, the pertinent chemical con-

stituents of the end product being N, 1.21 per cent; P_2O_5, 0.96 per cent; and K_2O, 0.65 per cent, or a total of 2.79 per cent, obviously higher than the values presented in the table above.

Three methods of handling refuse with sewage are considered: (1) addition of refuse at the source (kitchens, homes, etc.), (2) addition at several points on the sewerage system where flows are adequate, and (3) carriage of wastes to the sewage treatment plant and mixing with the sewage directly. Of the three methods, the third appears to be most economical. Sludge produced from the mixture of sewage and refuse does not have the fertilizer properties exhibited by those produced by the Beccari, Picco, or Dano processes. When consideration is given to the resale value of the end products, the Dano process seems most promising under Polish conditions.

CONRAD P. STRAUB

Chemical Problems in the Utilization of Sewage (Sludge) in Agriculture. BY LEONARD SKIBNIEWSKI. *Gaz, Woda i Technika Sanitarna* (Polish), **23**, 52 (Feb., 1949).

The chemical properties of humus are described. Sewage may be used as a fertilizer before or after treatment, but fresh sludge is not composed entirely of humus, as shreds of paper, fruit skins, fresh fecal matter, oils, and fats are not humus compounds. Also, organic fermentation products of digested sludge, even though homogeneous and black in color, cannot be considered as humus.

To determine the humus content, analytical analyses of dried sludges are carried out as follows: (1) the mineral salts, fats, and oils are separated from the dried solids; (2) the quantities of cellulose and other materials not suitable for the formation of humus are determined by treating the remaining sludge with suitable acids and alkalis; and (3) the amount of humus-producing material present is determined by subtracting the total of the above from the total solids initially present. It is also possible to ignite the sludge and determine the amount of humus present from the volume of CO_2 produced.

The amount of humus in various sludges as reported by Husmann are indicated in the following:

Type of Sludge	Humus (%)	Daily Production per Capita (gm.)	
		Humus	Organic
Fresh	33	16.5	35.0
Digested	35	14.0	20.0
Activated	41	20.5	35.0
From biological filters	47	18.8	24.0

The large amount of humus in activated sludge and biological filter sludge—that is, 41 and 47 per cent, respectively—indicates that primary treatment of domestic sewage does not remove the entire amount of humus-like material from the sewage as is so often erroneously believed. Further, it should be noted that digestion reduces the amount of humus-like material from 16.5 to 14 grams per person per day or about 15 per cent. This loss is compensated for in the digested sludge in that there is obtained a homogenous material which is without odor and which is easily absorbed by the soil.

Husmann also determined the nitrogen losses in sewage treatment. These losses amounted to about 40 per cent for biological filtration and about 25 per cent for activated sludge. The losses of nitrogen by filtration should be attributed to the fact that the wastes are sprayed or discharged in a thin stream onto the filtering medium, which results in a large loss of ammonia. Of greater interest than the loss in nitrogen are the changes in the various forms of nitrogen in the treatment process as indicated in the following:

Changes in the Forms of Nitrogen in Sewage Due to Treatment

Type of Treatment	Per Cent in Sewage		
	NH_3	Organic Nitrogen	Compounds of N
Primary	70–72	25–26	3
Biological filtration	35	16	50
Activated sludge	56	11	33

Even though a loss in the total nitrogen content is noted as a result of treatment, the fact that there is an increase in the compounds of nitrogen (nitrites and ni-

trates) is advantageous, as only these are readily available to plant life. Ammonia is not readily assimilated by plants. Therefore, when fields are irrigated while vegetating it is better to use treated or digested sludges, whereas in soils where the compounds of nitrogen have more time to undergo mineralization, irrigation utilizing raw sewage is more advantageous. Utilizing treated sludge has the further advantage that there will be no loss of nitrogen compounds to the atmosphere. Ammonia may be lost to the atmosphere if raw sewage is used for irrigation. There is no noticeable loss of potash and phosphorous during treatment. Biological sewage treatment results in a loss of humus, but may be added in the fields by mixing sludge from the filters with the effluent. By this means the cost of construction of filter facilities is reduced, as no digester space is required for digestion of the secondary sludge.

The author points out that raw sewage should not be applied to root vegetables usually eaten raw, but only to fields and meadows (pasture land).

CONRAD P. STRAUB

The Need for Pretreatment of Sewage Utilized for Agricultural Purposes. BY JAN WIERZBICKI. *Gaz, Woda i Technika Sanitarna* (Polish), **23**, 162 (May, 1949).

A high degree of treatment results from the agricultural use of sewage, along with the advantages of irrigation, fertilization, and enrichment of soil with humus. Because of this, treatment of sewage in conjunction with its use in agriculture is more justifiable economically than artificial biological secondary treatment. However, the hygienic aspect of diverting sewage for agricultural purposes must be taken into consideration, because of the millions of bacteria discharged and the possibility that pathogenic organisms and the eggs of enteric parasites may be present. In discussing the hygienic aspect, reference is made to Seifert's conclusions that fecal matter should not be used for irrigating lands on which foodstuffs that may be eaten raw (for example root vegetables) are grown, but could be used as a fertilizer for grazing land. However, these claims are not based on any studies. The experiences of Wroclaw (formerly Breslau), Berlin, and Jeny are cited, where the fields were irrigated with sewage and no ill effects were reported for periods up to 65 years. On the basis of the above, and results published by Zunker in 1941, the author concludes that primary treatment of the sewage is not necessary prior to disposal on fields for agricultural purposes.

Even though no real income may be shown by the disposal of sewage for agricultural purposes, consideration should be given to this method because of the increase in crop yields and the saving resulting from the fact that artificial treatment does not have to be provided. There is a wide degree of difference in the literature cited as to the amount of treatment required prior to discharge onto the fields: namely, from screens and racks up to secondary treatment. Clarified sewage is preferred for application to the irrigation fields. Pretreatment is recommended because: (1) much settleable material can be removed, toxic materials may be precipitated through coagulation, etc.; (2) removal of gross solids eliminates possibilities of clogging open or closed lines carrying the sewage; (3) many pathogenic organisms settle out with the settleable solids and are destroyed during the fermentation process; (4) removal of gross solids through sedimentation reduces complaints from odors which result from the discharge of raw sewage onto the irrigation fields; (5) removal of gross solids permits a lower level of flow in the sewers, but the flow is more rapid, which tends to prevent freezing in the winter months; (6) sedimentation reduces the possibility of the discharge of seeds (weeds, tomatoes, camomie, black nightshade, nettle, etc.) onto the irrigation fields because many are destroyed during digestion; and (7) sedimentation reduces the fly nuisance by preventing pooling of the sewage, which leads to the formation of breeding places for flies and mosquitoes.

Two disadvantages result from the pretreatment of sewage; namely, some of the fertilizer material is removed, and there is an increase in the cost of the use of these waters. Primary treatment reduces the fertilizer value of the sewage as follows: nitrogen, 10 per cent; K_2O, about 10 per cent; and P_2O_5, about 24 per cent. If the sludge is to be utilized as a fertilizer, some of these factors will be recovered.

CONRAD P. STRAUB

Removal of Phenol and Cresols from Natural Waters. By M. B. Ettinger and C. C. Ruchhoft. *Industrial and Engineering Chemistry*, **41**, 7, 1422 (July, 1949).

This paper describes experiments which indicate conclusively that biochemical dissimilation is a key factor in the dissipation of phenol in water. There is good evidence that purely mechanical removal by aeration is not an important factor in phenol reduction in streams. Inasmuch as temperature is an important factor governing the rate of microbiological action, the dissimilation of phenolic materials proceeds more rapidly at 20° C. than at 4° C. However, because temperature is by no means the only factor there are exceptions to this general rule. In general, phenol and cresols behave similarly under parallel conditions. Because of the unpredictable lags in phenol and cresol destruction there can be no fixed relationship between the amount of phenolic material introduced and the time it might endure in a stream. However, a chart is presented which gives a conservative estimate of the persistence of phenol (1,000 p.p.b.) in river waters of different types of 4° C. under aerobic conditions. This chart indicates roughly the following:

Types of Water	Time for Phenol Removal (days) 50% Removal	100% Removal
History of recent recovery from phenolic pollution; B.O.D. due to sewage over 3 p.p.m.	3	5.5
Sewage polluted; B.O.D. over 3 p.p.m.	5.5	7.5
Relatively pure; B.O.D. under 1 p.p.m.	14.0	20.0

Paul D. Haney

Increasing the Value of Waste Products. By E. C. Lathrop. *Proceedings* of the Third Industrial Waste Conference, pp. 8–15, Purdue University (1947).

The article discussed the utilization principally of agricultural waste products; for example, sugar bagasse, corn cobs and stalks, straw, seed-flax straw, cotton stalk, esparto grass, and lignin. It was pointed out that successful waste utilization was not a haphazard result. Four guiding principles for research were suggested: (1) Procure the waste material on a sound economic basis, (2) make a thorough study of the physical and chemical properties of the waste material to determine whether it might have a use not so readily supplied by other raw materials, (3) utilize a waste in process development, and (4) explore market possibilities and financial soundness before investing in plant scale work.

H. Gladys Swope

How Do You Determine When a Stream is Polluted? By W. E. Howland and R. B. Wiley. *Proceedings* of the Third Industrial Waste Conference, pp. 16–26, Purdue University (1947).

Pollution is defined as "an unwarranted or unreasonable amount of objectionable substances contributed to the natural water of a stream which, therefore, because of their amount and kind, should somehow be removed or counteracted by someone or prevented from entering the stream."

Unreasonable contamination brings in the question of economy in its broadest sense. In the 1943 regulations of the Indiana Stream Pollution Control Board pollution was considered in its economic sense when "there is a fair economic balance between cost of treatment of waste and benefits received, beyond which it is not reasonable to expend money for treatment, and the cost of treatment and the benefits to be derived must be considered in determining the extent of corrective treatment to be applied. . . ." In following out this line of reasoning a careful balance must be sought in the use of public funds for the many improvements required from all agencies.

Stream standards should be flexible and considered tentative. Minimum standards adopted by Indiana are:

1. Floating material, including grease and oil, shall not be discharged into any surface water in deleterious amounts, or in amounts sufficient to affect injuriously fish life, fur bearing or domestic animals, or the general biology of the water, or plant life in, or in the vicinity of, such water.

2. Waste which is discharged into any water shall contain nothing which will deposit in a stream or a lake to form putrescent or otherwise objectionable sludge banks.

3. Waste which is discharged into any water shall contain no materials in con-

centrations sufficiently high to affect adversely public health, fish life, fur bearing or domestic animals, or plant life in, or in the vicinity of, such water.

4. Generally, the oxygen content of the receiving water, after being mixed with and affected by the waste, shall be no less than 50 per cent saturation. A lower concentration will be tolerated temporarily, but only so long as it is not injurious to aquatic life, and in no case shall it fall below 25 per cent saturation.

5. Receiving waters shall be considered unsuitable for bathing if the coliform concentration exceeds 1,000 per 100 ml. (M.P.N.). If the receiving water is used as a source of water supply, a coliform density greater than 5,000 per 100 ml. (M.P.N.) shall not exist at or in the vicinity of the intake. Also in the case of wastes bearing or producing substances objectionable from a taste or odor standpoint, which are discharged into waters which are used as a source of water supply, such wastes shall be so treated as to render them unobjectionable before discharge into the stream or lake.

H. GLADYS SWOPE

The Flowing Stream—One More World. BY SHELBY D. GERKING. *Proceedings* of the Third Industrial Waste Conference, pp. 27–33, Purdue University (1947).

Pollutants harmful to fish life are classed in two categories: those which reduce the dissolved oxygen and those which have a direct toxic effect. Five p.p.m. of dissolved oxygen (D.O.) is given as the minimum for maintaining a varied fish fauna in summer in the midwestern streams.

Toxic chemicals enter the body of the fish by diffusion through the gills, lining of the mouth, and external structures. Acids and salts of heavy metals combine readily with mucus secreted by the fish and cause a heavy precipitate over the whole body and the gills. The precipitate interfers with the diffusion of oxygen through the gill membrane. Excretion of sodium chloride and nitrogenous wastes through the gill membrane is also blocked by heavy mucus formation.

Some toxic wastes enter the body when the fish swallows water. These poisonous substances are either absorbed by the gastrointestinal tract or may damage the intestinal lining sufficiently to cause death. Other toxic wastes cause minute lesions.

The number and type of species present in a stream is a measure of the presence or absence of pollution. Experience has shown that the absence of darters is usually good evidence that some form of pollution is present.

The number of species found in various Indiana rivers in different years is discussed.

H. GLADYS SWOPE

Kansas' Attitude on Industrial Wastes. BY B. L. WILLIAMSON. *Proceedings* of the Third Industrial Waste Conference, pp. 34–37, Purdue University (1947).

The major industrial waste problem in Kansas is the disposal of oil-field brines. In 1935 the legislature passed two acts governing their disposal—one allowed the return of oil-field brines into proper subsurface formations and the other allowed repressuring or water flooding of oil properties.

In 1947 the legislature amended a 1933 law which permitted the storage of salt water and oil waste in ponds, prohibiting this method of disposal, as the method resulted in pollution of both surface and sub-surface waters.

In July, 1935, the Oil Field Waste Disposal Section of the Division of Sanitation of the Kansas State Board of Health was formed. For financing this program of research and education an assessment of $0.0004 was made per barrel of petroleum produced and sold each month. The general program of this Section comprised: (1) checking complaints, (2) inspection of brine and oil waste disposal methods, (3) special field surveys and studies, (4) major stream pollution cases, (5) casing programs for disposal wells, (6) furthering community disposal-well projects, (7) water flood projects, (8) bottom-hole cementing, (9) recommendations to abandon small oil producers having an excessive oil-water ratio, (10) state service work, and (11) an educational program.

Kansas' attitude toward the use of its streams is one of reasonable use, but it is recognized that "no one has the right to degrade streams to such extent as to prohibit their use by others."

H. GLADYS SWOPE

The Importance of Fundamental Research in Waste Treatment Problems. By Harry W. Gehm. *Proceedings* of the Third Industrial Waste Conference, pp. 61–64, Purdue University (1947).

Discusses the importance of basic research for solving the problems of treatment of strawboard and deinking wastes. Much of the pollutional characteristics of these wastes are in the colloidal state, making the solution of this problem difficult.

H. Gladys Swope

Annual Report of the City Engineer, Johannesburg, South Africa, for the Year Ended June 30, 1948. By H. Schrader.

Expenditures for enlargement of present works are delayed pending construction of a new works. The Antea works operate on an overload of 66 per cent on the designed capacity. The Bruma works are nearing their ultimate capacity.

At the Cydna works, recirculation of humus tank effluent to the dosing tank of the trickling filters (0.4 effluent to 1 settled sewage) has proven helpful in permitting increased loading, reducing odors, and controlling psychoda flies.

The Delta and Klipspruit works are suffering from increased flow and overload.

The application of 0.68 lb. of benzinehexachloride per filter unit (100 ft. diam. × 6 ft. deep) via the dosing tank within a period of 20 min. proved helpful in fly control.

The use of digested sludge was restricted to municipally cultivated lands, because of the outbreak of poliomyelitis, although the health authorities have failed to implicate sewage disposal practice during epidemics with the spread of the disease.

Recirculation of effluent at Klipspruit began experimentally on April 25, 1947, using settled sewage mixed with humus-free filter effluent on four trickling filters 100 ft. in diameter and 6 ft. deep, in an over-all ratio of 1:1. The rates used ranged from 72 to 145 Imp. g.p.d. per cu. yd. Apparently, a rate of 125 Imp. g.p.d. per cu. yd. was as high as practicable, maintaining nitrate (11 p.p.m.). The rate of dosing varied during the 24 hr. Recirculation obviated odors at the dosing tank and filter surface and lengthened the period between cleaning.

Sewage effluents are used to irrigate farms which are used for grazing, with a return of $62,356. Cattle fattening brought in $21,548. Sales of cattle showed a profit of $11,836. On one farm, 900 head per day graze on 300 acres.

The total revenue from all operations was $111,672, of which all but $2,904 came from Klipspruit and Oliphantsvlei. About $4,944 was realized from the sale of sludge, and $13,652 from the sale of produce, largely hay and mealies.

Langdon Pearse

Fundamentals in Sewage Effluent Recirculation. *The Surveyor*, **108**, 393 (July 1, 1949).

This article is a report of the discussion of a paper of the above title delivered at the North Eastern Branch meeting of the Institute of Sewage Purification. The paper was written by W. Watson and S. R. Twine of the Keighley Corporation sewage works. The tests described in the paper were made to determine the effect of returning settled filter effluent to the unsettled sewage, although the scheme adapted for the Keighley works provided the return of settled final effluent to the settled sewage.

Different theories of recirculation in trickling filters have been advanced by various authorities. It has been suggested that ponding does not occur with recirulation because the higher rate of flow flushes out the solids; others have maintained that the reverse may be true. One authority maintains that diluting the sewage for recirculation starves the organisms and another maintains that recirculation is a means of providing more food. "The authors were of the opinion that the action of recirculation was probably due mainly to dissolved oxygen, nitrates and nitrites, and aerobic filter organisms from the effluent being introduced into the sewage prior to treatment on the filter, which results in an entirely different kind of life in the filter itself—at any rate, quite different from that in the upper layers of the conventional filter treating plain settled sewage."

In discussions of the paper the view was expressed that three factors were responsible for improvement by recirculation—presence of dissolved oxygen, presence of oxidized nitrogen, and continuous inoculation with aerobic and nitrating organ-

isms. The value of nitrates in a sedimentation tank was brought out in the paper, but in a clean filter bed where aerobic conditions prevailed it would appear that nitrates were unnecessary.

Another view expressed was to the effect that recirculation and double filtration were useful tools for those charged with designing and enlarging sewage works, and that it appeared that the greatest field for recirculation at present was its application to the relief of existing overloaded filter installations. Possible alternatives in applying recirculation to existing plants were discussed. It was felt that much remained to be learned along these lines.

The question of humus tanks was discussed at some length. At Keighley it was reported that often finely divided humus was produced which did not settle well in tanks having capacity enough to retain the dry weather flow for 5 hr. The possibility of this being due to the effect of synthetic detergents was mentioned. At another plant the capacity of the humus tanks was only enough to retain the dry weather flow for $1\frac{3}{4}$ hr. and the settling was rather inferior. It appeared that the effluent contained more suspended matter now than formerly.

Owing to the low capacity of these tanks effluents containing 30 to 60 p.p.m. of solids were being recirculated. It was felt that this material might be helpful if the filter medium were sufficiently large.

Another view expressed was that it was the practice in England to retain sewage too long in the primary settling tanks, with periods of 10, 14, and up to 20 hr.

T. L. HERRICK

Filtration of Part Flow of Primary Tank Effluent in Admixture with Humus Tank Effluent from Remaining Flow. BY F. OLIVER. *The Surveyor*, **108**, 469 (August 5, 1949).

The Harrogate Northern sewage works provides primary settling, trickling filter treatment, and settling in humus tanks for the normal dry weather flow. Stormwater flow in excess of three times the dry-weather flow is settled and passed through three trickling filters operated in parallel. These filters are 80 ft. in diameter and are equipped with rotary distributors. The depth of filter medium is 4 ft., the bottom 18 in. of which is half-bricks, the remainder being hard burned clinker of $1\frac{1}{2}$-in. grade.

Test Period	9/24/47–3/2/48	3/3/48–6/15/48	6/16/48–10/18/48	10/19/48–12/16/48
Primary tank effluent (g.p.h.)	10,400	10,500	10,500	13,100
Humus tank effluent (g.p.h.)	10,400	14,000	14,300	17,700
Dosage to works filters (g.p.d./cu. yd.)	71	71	71	67
Dosage to "dilution" filters (g.p.d./cu. yd.)				
Gross	224	263	400[2]	400[2]
Tank effluent	112	114	169[4]	169[2]
Gross				163[3]
Tank effluent				113[3]
N as nitrates (p.p.m.)				
Humus tank effluent	20.2	31.4	31.0	30.5[2]
				30.2[3]
Mixed feed	10.1	15.8	12.4	15.7[2]
				14.3[3]
"Dilution" effluent (f)	20.3	32.2	24.3	30.7[2]
				29.5[3]
5-day B.O.D. (p.p.m.)				
Settling tank effluent	175.0[4]	253.5[5]	—	188.0[2]
Humus tank effluent	13.0[4]	12.9[5]	—	—
Mixed feed	91.5[4]	—	—	—
"Dilution" effluent[6]	17.6[4]	13.4[5]	—	8.8[2]

[1] Rates during 16 hr. actual operation. When calculated to 24 hr. the rates are 266 and 133
[2] 8 A.M. to 8 P.M.
[3] 8 P.M. to 8 A.M.
[4] Average of fewer samples than for other determinations.
[5] One sample only.
[6] After 1 hr. settling.

Results were not satisfactory when operated as storm-water beds exclusively. Results were improved by dosing the filters for 3 hr. each day with settling tank effluent. A decision to divert flow to the works from an adjacent area made it necessary to find means of utilizing these filters to the fullest extent possible. Tests were made on the use of these units as expressed in the title of the paper; a part of the humus tank effluent from the main plant was mixed with a portion of the flow from the primary settling tanks and the mixture was dosed on the storm-water filters. The table shows the results obtained during the four test periods.

The results have been so promising that it is planned to build a fourth filter and humus tanks to serve all of the filters. The layout is quite flexible and the filters can be used in three ways—as "dilution" filters, as storm-water filters, and as the second stage of a double filtration plant. An improvement has been noted when the filters are used as storm-water filters. As expected, the quality of the effluent from the main filters has been improved by the shift of a portion (one fifth) of the sewage flow to the dilution filters.

T. L. HERRICK

The Proposed Blackstone Valley Sewage and Wastes Collection System and Treatment Works. By E. S. CHASE. *Journal Boston Society of Civil Engineers*, **36**, 2, 165–191 (Apr. 1949).

The Blackstone Valley Sewer District lies in Rhode Island and includes the cities of Pawtucket and Central Falls and three towns, with a municipal area of 75 sq. mi. The cities are largely built up with residences or business structures. Pawtucket discharges into the Blackstone and Seekonk rivers, a part going to Providence sewers. Central Falls has an old, inefficient plant handling part of the sewage. East Providence sewage is partly sewered, and treated by sedimentation and chlorination, discharging into the Providence River. Most of the industrial wastes of all municipalities discharge untreated to the several streams.

The Blackstone, Moshassuck, and Seekonk Rivers are grossly polluted by sewage and industrial wastes originating within the District. The Blackstone River is seriously polluted when it enters the District. The Seekonk is also grossly polluted and accumulates offensive sludge.

The population of the District was about 170,000 in 1948 and is expected to increase to 221,800 in 1975. Its public water consumption in 1947 averaged 100 g.p.d. per capita (16 m.g.d.). Private supplies provide more than 200 g.p.d. per capita (35 m.g.d.). About 85 per cent of the daily water use is for industry. About 34 m.g.d. of industrial wastes go direct to the streams and 3.5 m.g.d. to the sewers. The combined sewage and industrial wastes total about 50 m.g.d. About 13 m.g.d. of industrial wastes are weak enough to go direct to the streams. However, the effluent from a finishing plant is highly alkaline, and high in dissolved organic matter.

The District sewage discharges into Narragansett Bay and affects shellfish laying as well as recreational use of the waters. Plans for interception of sewage and wastes were developed with treatment, except for the finishing plant wastes, which require separate treatment.

About 75 per cent of the flow is industrial. Of this, 12.65 m.g.d. can be discharged directly.

The intercepting sewers are recommended for design as of the year 2000; the treatment works, as of 1975, or about 25 years hence. The Blackstone Valley interceptor will serve about 10,250 acres and an estimated population of about 172,000 in the year 2000. The Moshassuck interceptor will serve about 3,500 acres and 56,000 persons. Several smaller interceptors are required.

Six treatment plants are proposed, of which the largest (Bucklin Point) is planned for 158,000 population and 47 m.g.d. as of 1975, with a total equivalent population of about 400,000. This plant includes pre-aeration tanks, sedimentation, and chlorination, with sludge digestion, elutriation, vacuum filters, and incineration. Three small plants will require Imhoff tanks, high-rate trickling filters, and chlorination.

The estimated construction cost of the entire project is $15,662,000. Annual fixed charges amount to $939,800; operating costs, $393,000. Progressive development is suggested for a $5,324,000 project, followed by a second step of $4,417,000, and a final step of $5,921,000.

The enabling act permits the Commission to assess the municipalities and industries within the District reasonable charges for the use of the sewerage project. The simplest method is based on volume, but any schedule of rates should provide for extraordinary concentrations of impurities discharged. In the first stage of the project (20 m.g.d.), it is estimated that 6.5¢ per 1,000 gal. would provide the necessary funds.

LANGDON PEARSE

Water Pollution Research. *The Surveyor*, **108**, 217 (April 15, 1949).

The report of the Water Pollution Research Board for the year 1947 contains accounts of investigations of several important subjects. The section devoted to sewage treatment is concerned cheifly with biological filtration. It is noted that results obtained at a semi-scale plant at the Finham works at Coventry on double filtration and on recirculation of effluent were not as promising as those obtained at the Minworth works at Birmingham. Considerable trouble from ponding is experienced at Coventry.

In the use of DDT and Gammexane in the control of filter flies it is necessary to consider more than one possible secondary effect. The possibility of producing an effluent toxic to fish is one; the other is that the drastic control of flies may result in the accumulation of solid matter in the filters as fly larvae are very useful scavengers. However, both chemicals appear to be quite selective and the dosages can be so adjusted that flies are controlled without ill effects on the degree of treatment.

T. L. HERRICK

Sewage Purification Problems. BY C. JEPSON. *The Surveyor*, **108**, 375 (June 24, 1949).

This paper is of a general nature. The main topics discussed are works design and layout, synthetic detergents, works rehabilitation, sludge disposal, and control of population of rivers and streams.

T. L. HERRICK

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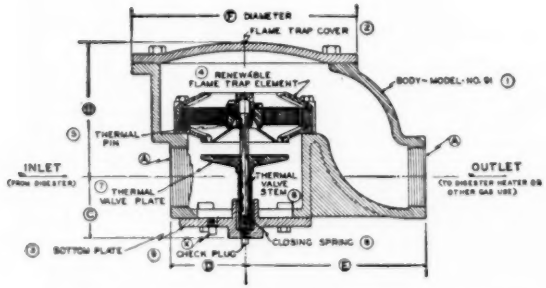

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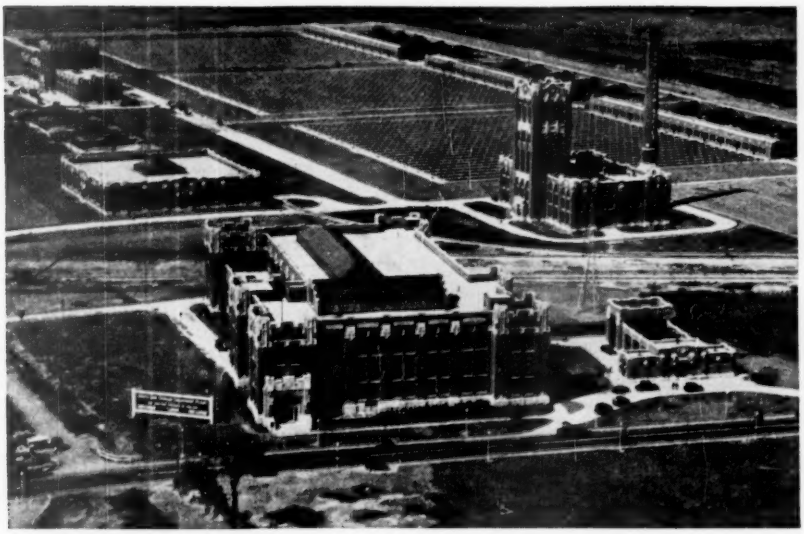

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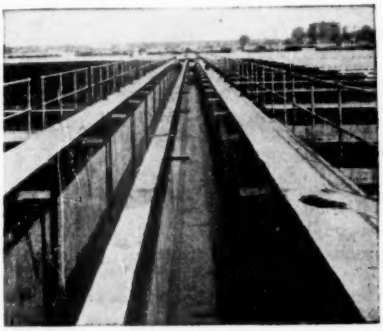

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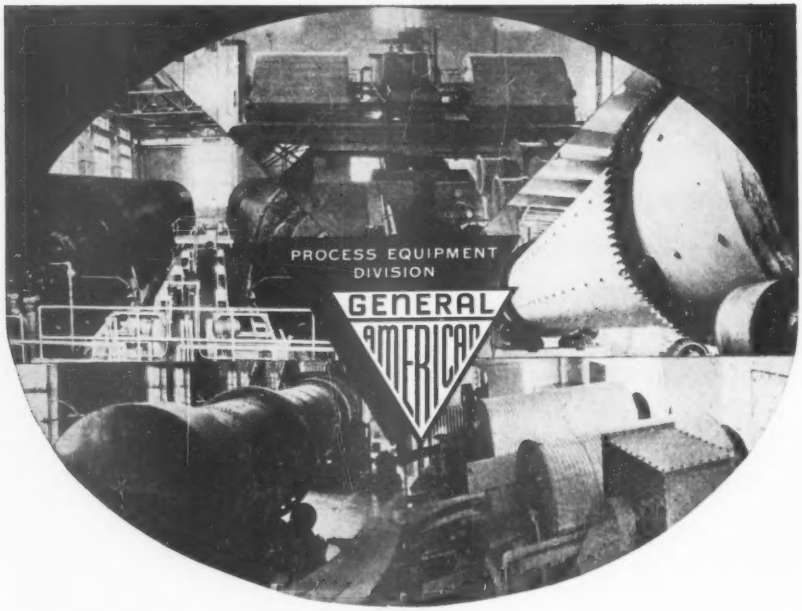

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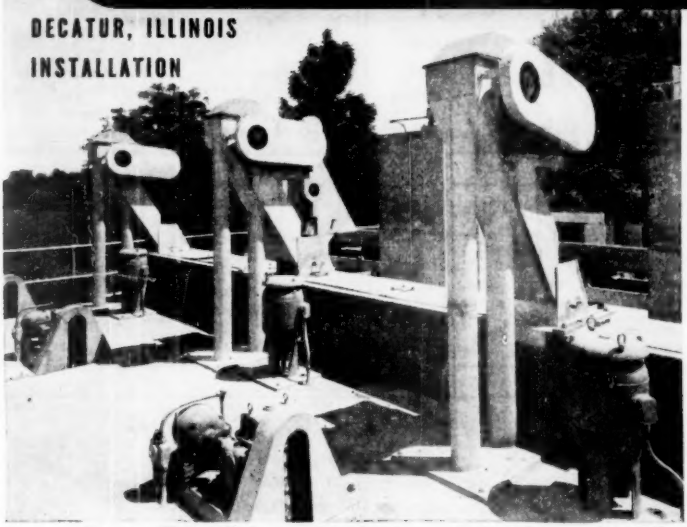

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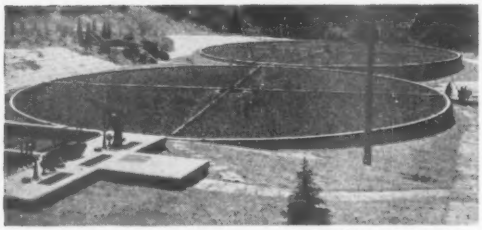

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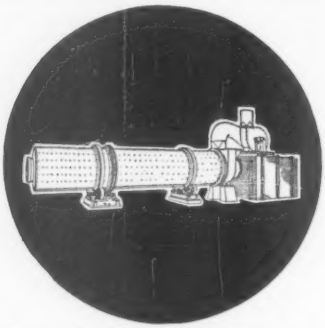

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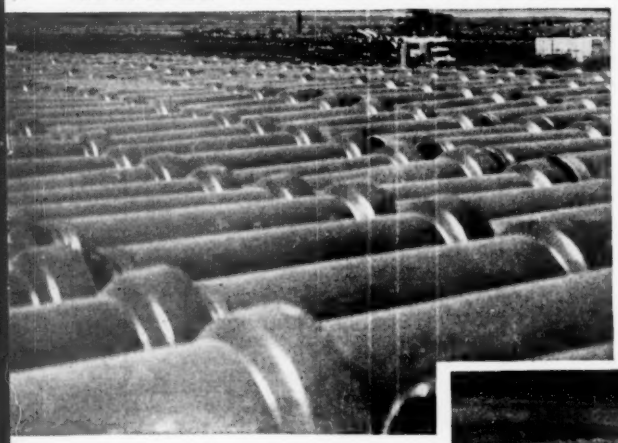

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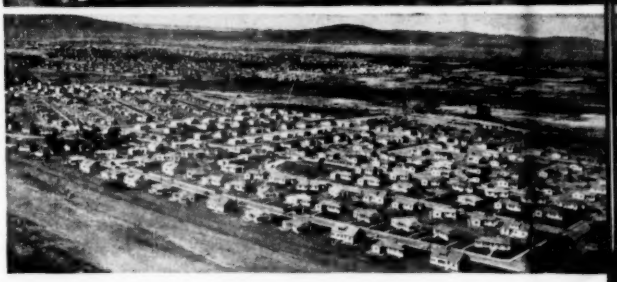

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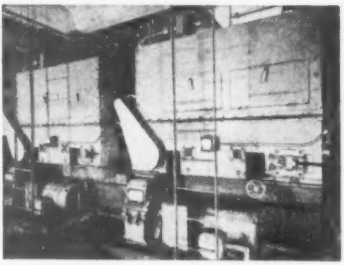

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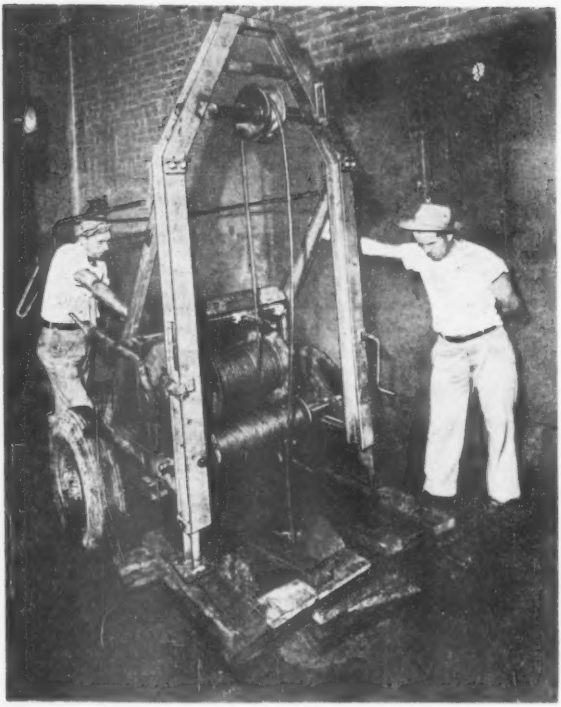

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